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SEDIMENT STATION ANALYSIS: SOUTH SASKATCHEWAN RIVER AT SASKATOON - 05HG001

HARDY BST LIMITED

WATER RESOURCES BRANCH
LAND AND WATERS DIRECTORATE
DIRECTION DES RESSOURCES EN EAU
DIRECTION GÉNÉRALE DES EAUX INTÉRIEURES

Canada

Western and Northern Region

SEDIMENT STATION ANALYSIS
SOUTH SASKATCHEWAN RIVER AT SASKATOON
05HG001

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Prepared for:

ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
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WESTERN AND NORTHERN REGION
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ABSTRACT

This is one of a series of sediment station analysis reports issued by the Water Resources Branch of Environment Canada. The report was prepared by Hardy BBT Limited under contract to the Department of Supply and Services. It presents a summary and analysis of the sediment data for the South Saskatchewan River at Saskatoon, Saskatchewan (Sta. 05HG001, for the period 1961 - 1971, and 1975). The data have also been assessed in terms of the impacts of the Gardiner Dam, channel morphology and effects on Codette Reservoir sedimentation.

Notwithstanding the general reduction in sediment loads resulting from the operation of Gardiner Dam, the data base indicates that substantial suspended sediment loads can be transported past Saskatoon. This may affect the projected life expectancies for Codette Reservoir and Tobin Lake.

It has been concluded that the available sediment data on the South Saskatchewan River at Saskatoon sufficiently describe the annual and monthly sediment regime. However, the data base appears to be deficient in fully describing the flow regimes for higher flows, and especially the trap efficiency of Gardiner Dam.

It is recommended that the sediment data collection program on the South Saskatchewan River at Saskatoon be re-established on a special event basis to document sediment discharges for flows >1500 m^3/s. Suspended sediment particle size data should also be collected to determine the type of material being transported.

Table A summarizes major sediment parameters derived from the data base.

RÉSUMÉ

Une réalisation de la société Hardy BBT Limited dans le cadre d'un marché conclu avec le ministère des Approvisionnements et Services, le présent rapport constitue l'un d'une série de rapports d'analyse concernant des stations d'étude des sédiments publié par la Direction des ressources en eau d'Environnement Canada. Le rapport présente un sommaire et une analyse des données relatives aux sédiments de la rivière Saskatchewan Sud à Saskatoon, en Saskatchewan (station 05HG001, de 1961 à 1971 et en 1975). Les données ont également été évaluées en rapport aux répercussions du barrage Gardiner, à la morphologie du chenal et aux effets sur la sédimentation du réservoir Codette.

Malgré la diminution générale du charriage de fond entraînée par le fonctionnement du barrage Gardiner, les données de base indiquent que des quantités importantes de matières en suspension sont transportées au-delà de Saskatoon. Ce phénomène pourrait affecter les durées de vie utile projetées pour le réservoir Codette et le lac Tobin.

Il a été conclu que les données disponibles sur les sédiments de la rivière Saskatchewan Sud à Saskatoon permettent de décrire suffisamment le régime annuel et mensuel des sédiments. Toutefois, la base de données semble être inadéquate, car elle empêche de décrire entièrement le régime d'écoulement pour des débits plus éléves et, tout particulièrement, l'efficacité du barrage Gardiner à retenir les sédiments.

Il est recommandé de réétablir le programme de collecte de données sur la rivière Saskatchewan Sud, à Saskatoon, de façon à tenir compte des événements spéciaux et permettre de documenter les débits solides pour des débits supérieurs à 1500 m^3/s. Les données sur la granulométrie des sédiments en suspension devraient aussi être recueillies afin de préciser le type de matières transportées.

TABLE A

SUMMARY OF SEDIMENT DATABASE
SOUTH SASKATCHEWAN RIVER AT SASKATOON
W.S.C. STATION 05HG001
1961 - 1971, 1975

Drainage Area: Gross = 141 000 km², Effective = 88 200 km²

Channel Stability: laterally stable; aggradation completed upstream of weir

Slope = 0.00024

Hydraulic Data: (see Figure 12)

Bed Material: Gravel (4%), Sand (85%), Silt and Clay (11%)
D_{50} = 0.247 mm

Suspended Sediment: Sand (42.4%), Silt (39.4%), Clay (18.2%)
D_{50} = 0.055 mm

Suspended Sediment Data Range:

	Loads (tonnes)	Concentrations (mg/L)
Daily	7.05 to 323 000	2 to 2510
Annual	91 900 to 4 060 000	16 to 220

Mean Annual Suspended Sediment Load: 1 630 000 t

Mean Annual Suspended Sediment Concentration: 88.6 mg/L

Percentage of Mean Annual Load: transported in 1 day = 5.4%, 4 days = 17%, 37 days = 52%

Seasonal Variations: Percent of Annual Load Transported Each Month

January	.88
February	9.7
March	1.2
April	11.0
May	11.0
June	30.0
July	39.0
August	2.6
September	1.2
October	1.2
November	0.92
December	0.69

ACKNOWLEDGEMENTS

Thanks are expressed to Ross Herrington, Regional Engineer with the Water Resources Branch in Regina, who was Scientific Authority for the contract, and provided review comments and data. T.R. Yuzyk of the Sediment Survey in Ottawa, provided comments and information. J. McIlhinney of the same office was responsible for the computer plots. Bob Abernethy of Sask. Power, provided data and reports o. Codette Reservoir sedimentation. Randy Munk of the City of Saskatoon, Water Works and Glen Grismer of the Meewasin Valley Authority, provided local background information. Comparative river cross-sections were obtained from T. Bellasantos of the City of Saskatoon, Engineering Department.

The report was prepared by Gary R.E. Beckstead, P.Eng., with assistance from Mrs. Monica Freeman, E.I.T. Mr. Wim M. Veldman, P.Eng. provided review comments. Word processing was done by Mrs. R. Baksh, Mrs. G. Weitz and Ms. S. Chow. Mr. G. Evenson carried out the drafting.

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1.0 INTRODUCTION

1.1 HISTORY AND PURPOSE OF THE SEDIMENT PROGRAM

In June 1961, the Water Resources Branch of Environment Canada initiated a sediment sampling program on the South Saskatchewan River at Saskatoon, (Water Survey of Canada - WSC - Station 05HG001). This site was selected to be included as a part of the network of Canadian sediment monitoring stations, gathering data on sediment yield for water development projects. Specifically, the Saskatoon site was established to determine the impacts of the Gardiner Dam (and its reservoir, Lake Diefenbaker) on the sediment regime of the South Saskatchewan River.

1.2 PURPOSE OF THIS REPORT

The purpose of this report is to compile a summary and assessment of the existing sediment data for the South Saskatchewan River at Saskatoon, and to assist the Water Resources Branch in reviewing the operation of this station relative to the data and information gathered. In addition, as requested in the terms of reference, this report also evaluates:

- the impacts of Gardiner Dam/Lake Diefenbaker on sediment loads,
- the relationship between sediment loads at Saskatoon and the morphology of the South Saskatchewan River,
- the role of the South Saskatchewan River in transporting sediment which may impact Codette Reservoir on the Saskatchewan River,

- the adequacy of the existing sediment data base for possible engineering, environmental and water quality applications, and
- planning future sediment program activities.

1.3 SCOPE OF REPORT

This report reviews the sediment data collected during the 12-year period from 1961 -1971 and 1975. These data are primarily of suspended sediment, but include bed material data as well.

In Chapter 2, brief descriptions of the Saskatoon station, the local river reach and the South Saskatchewan River basin are presented.

The summary of suspended sediment data is presented in Chapter 3, and suspended sediment transport is discussed in Chapter 4. Supplementary information, including hydraulic relationships, bed material data and dissolved solids data are also discussed in Chapter 4.

Chapter 5 contains a discussion of the impacts of Gardiner Dam on sediment transport, and presents a discussion of the relationships between sediment loads at Saskatoon and the morphology of the South Saskatchewan River.

In Chapter 6, the role of the South Saskatchewan River in transporting sediment which may impact Codette Reservoir on the Saskatchewan River is discussed.

Conclusions and recommendations are contained in Chapter 7.

2.0 BACKGROUND

2.1 HYDROMETRIC STATION DESCRIPTION

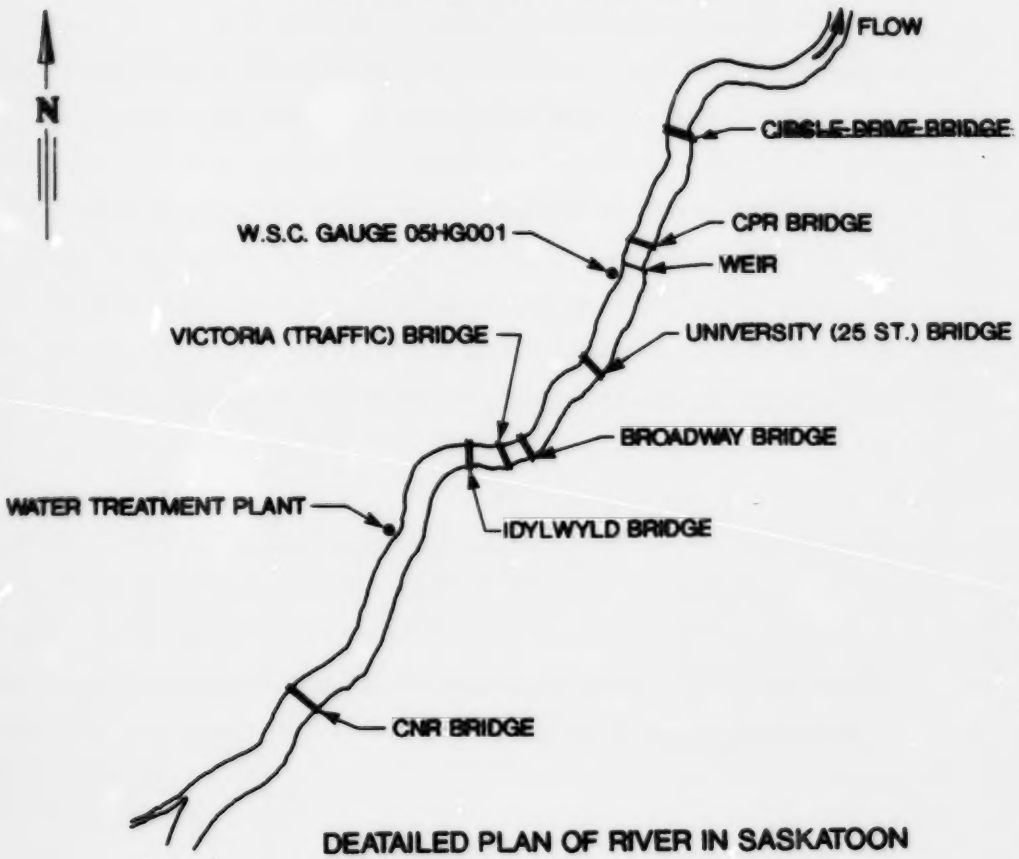
Water level and streamflow records have been collected for the South Saskatchewan River at Saskatoon on a continuous basis since June 1911. The present gauging shelter is located on the left bank of the river approximately 75 m upstream of the weir and 1400 m downstream of the University Bridge. The location of the gauge which was established at this particular site in 1962, is illustrated in Figure 1.

The instrumentation consists of a Leupold and Stevens A-71 strip chart recorder driven by a pressure-sensing STACOM servo-manometer system. A Telemark has also been installed at this site. All instruments are housed in a metal shelter, (see Photograph 1, Appendix A).

Streamflow discharge measurements are taken from the Idylwyld (freeway) Bridge, 3200 m upstream of the gauge. In the past, discharge measurements were also conducted from a catamaran boat, at a site approximately 800 m downstream of the gauge, from the CPR railway bridge (300 m downstream of the gauge), or from the Traffic Bridge, where the gauge was situated prior to 1962, (Figure 1).

The stage versus discharge relationship at this station is relatively stable, due to the controlling influence of the weir constructed in 1939-40 (Figure 2). Flows less than 3300 m^3/s are controlled by the weir. In-filling of the river banks due to aggradation upstream of the weir has narrowed the channel significantly, so that when the weir becomes fully submerged (discharges

SOUTH SASKATCHEWAN RIVER BASIN



DEATAILED PLAN OF RIVER IN SASKATOON

Figure 1 Location Plan

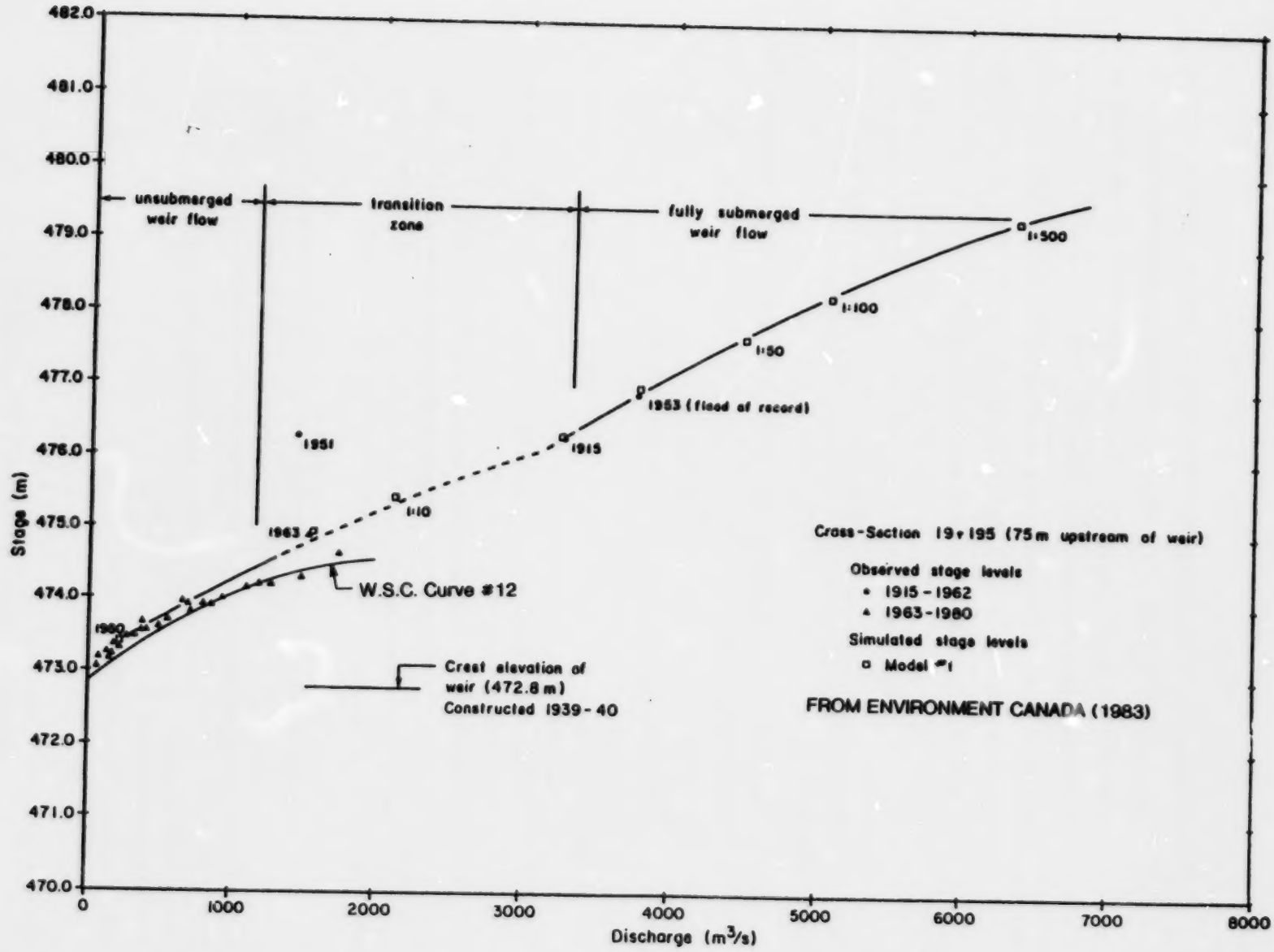


Figure 2 Stage-Discharge Curves

>3300 m^3/s), hydraulic control will shift to the encroached sections (Environment Canada, 1983). Twelve rating curves have been used by the WSC over the past 77 years. Curve No. 12, dated March 16, 1988, indicates some instability in the curve for flows less than 140 m^3/s; i.e., as much as 0.012m at 25 m^3/s. Figure 3 illustrates comparative cross-sections, based on surveys conducted in 1952 and 1979, which indicate that the river has narrowed as a result of infilling on the floodplain to stabilize the valley walls.

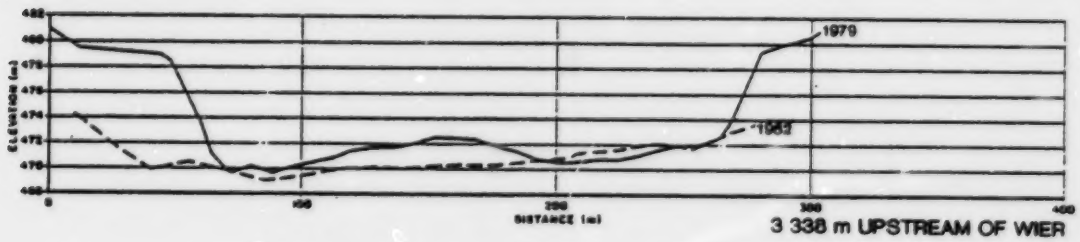
2.2 BASIN DESCRIPTION AND HYDROLOGY

The following description has been excerpted from Saskatchewan Environment (1980).

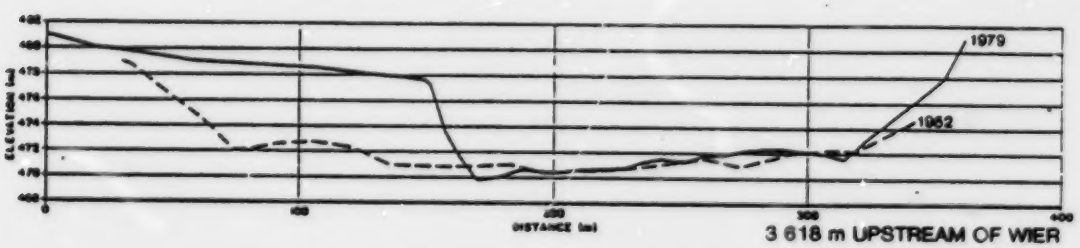
The South Saskatchewan River receives water from tributaries in southern Alberta, Saskatchewan, and northwestern Montana as shown on the Basin Plan, (Figure 1). The main tributaries, the Red Deer, Bow, Oldman, St. Mary's and Waterton Rivers, have their headwaters on the eastern slopes of the Rocky Mountains and the foothills. Spring runoff in these rivers originates from three sources: the mountain snow pack, the foothills snow pack and the prairies snow pack. The snow pack tends to be much larger in the mountains than the foothills or prairies due to greater accumulation of snow at the higher elevations. Peak flows from the foothills and prairie runoff occur in April and May, followed by a peak flow from the mountain runoff in June. The relative magnitudes of these peaks may vary but generally the mountain runoff peak is largest.

The basin lies in the cool temperate zone. Average annual temperatures are in the range of from 5.6°C at Fort Macleod to 2.6° at Red Deer in Alberta while the Saskatchewan portion of the basin is characterized by Saskatoon's mean annual temperature of 1.6°C.

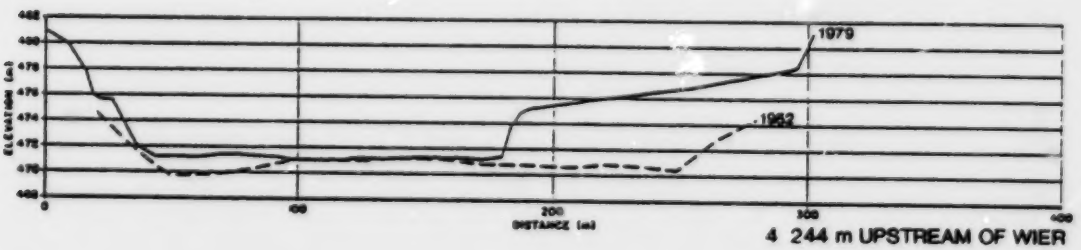
2 752 m UPSTREAM OF WIER



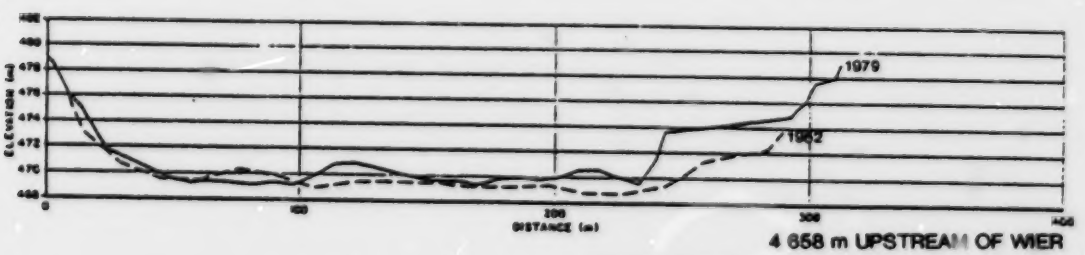
3 338 m UPSTREAM OF WIER



3 618 m UPSTREAM OF WIER



4 244 m UPSTREAM OF WIER



4 658 m UPSTREAM OF WIER

FROM ENVIRONMENT CANADA (1983)

Figure 3 Comparative Cross-Sections

The basin is classified as semi-arid to sub-humid with the south and southwest areas being mainly semi-arid. Annual precipitation is in the range of from 770 mm in the mountains (at Lake Louise), to 540 mm in the foothills (Pincher Creek) and 350 mm on the plains (Medicine Hat and Saskatoon). Of this total precipitation snowfall accounts for 63% at Lake Louise, 56% at Pincher Creek, 35% at Medicine Hat and 32% at Saskatoon. Spring rains during the runoff season of April, May and June account for the following percentages of the total precipitation: Lake Louise 13%, Pincher Creek 30%, Medicine Hat 32% and Saskatoon 29%.

Historically major flood events in the South Saskatchewan River at Saskatoon have been a combination of a major rainstorm covering most of the basin coinciding with a high mountain snow pack runoff. The magnitude of the peak flow is mainly a function of the extent and intensity of the rain storm and the mountain snow melt.

Developments in the South Saskatchewan River Basin in Alberta have affected the South Saskatchewan River flows in several ways.

Irrigation developments which began in the early 1900s have increased in size and represent a major use of water. Diversion of water to offstream storage usually takes place during peak runoff periods, although some projects on the Bow and Oldman Rivers divert water for irrigation throughout the irrigation season. The result is that spring peaks and summer flows are reduced.

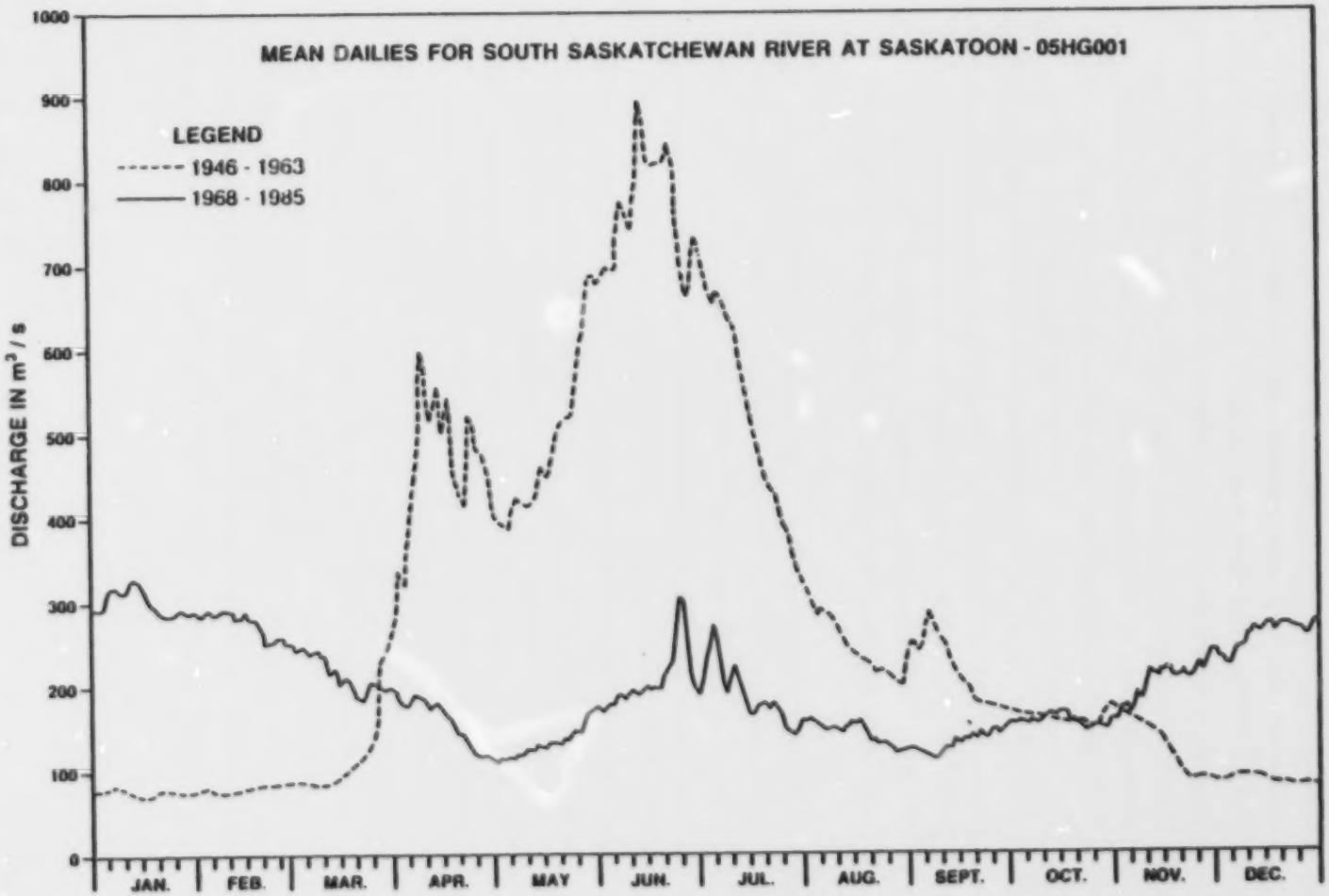
Return flows from some irrigation developments which receive water from the Bow River enter the Red Deer River. This results in increased flows in the Red Deer River and a change in the pattern of flows due to the lag time caused by the irrigation and drainage works.

Hydroelectric power development in the upper Bow River Basin has changed the patterns of flows in the Bow River. Spring runoff peaks are reduced as water is stored for power production and winter flows are increased as power is being generated to meet energy demands.

The South Saskatchewan River system has undergone many changes throughout the last 100 years as agricultural development and urban settlements have grown but the most significant change occurred in 1968 when the South Saskatchewan River Project was completed and Lake Diefenbaker was formed. (The impacts of Gardiner Dam/Lake Diefenbaker on the sediment regime of the South Saskatchewan River is discussed in Chapter 5). This lake, formed by the Gardiner Dam on the South Saskatchewan River at Cutbank and the Qu'Appelle arm, extends west from Gardiner Dam about 230 km to about the Lemsford Ferry site. It has a total storage capacity of 9.4 x 10^9 cubic metres (m^3) with live storage of 4.0 x $10^9 m^3$. At Gardiner Dam the Saskatchewan Power Corporation operates its Coteau Creek hydroelectric generating plant, which can generate 187,500 kilowatts at peak capacity while releasing 425 cubic metres per second (m^3/s). The spillway at Gardiner Dam has a capacity of about 6,380 m^3/s with all eleven gates open and the water level at the spillway at the full supply level (FSL) of 556.86 m.

The operation of the lake has changed the annual pattern of flow in the South Saskatchewan River at Saskatoon. Prior to the creation of Lake Diefenbaker the peak flow generally occurred at Saskatoon in April, June or July (Figure 4) when the spring runoff from the foothills, plains or the east slope of the Rocky Mountains reached the city. With the lake now operated for municipal and industrial water supply, irrigation, power production and recreational purposes, peak flows at Saskatoon often occur during the winter months when the reservoir is being drawn down to generate hydroelectric power and when power demands are highest. The spring runoff is now stored as much as possible in the reservoir which results in peak flows near the power plant capacity of 425 m^3/s during the winter, flows occasionally in excess of this in spring and low flows, sometimes reaching the minimum desirable of 43 m^3/s, in the summer and early fall.

During the operational history of the reservoir, since 1968, spills have occurred four times. On these occasions the annual peak flow at Saskatoon was the result of the spill. This will be the case whenever spills occur. Spills will most often take place during June or July. Lake Diefenbaker is not operated as a flood control reservoir but normal operations have a significant effect on the peak flows that reach Saskatoon during high flow years.



FROM YUZYK (1987)

Figure 4 Pre-Reservoir and Post-Reservoir Flow Regimes

Numerous gauging stations are presently operating or have operated in the South Saskatchewan River Basin. Sediment data have been gathered at several of these sites as well. Some of these sites have been the subject of sediment station analyses, (Day and Spitzer, 1985a, 1985b; Hydrocon, 1987), a sediment transport analysis (Ashmore, 1986), and an interpretative study of sediment regime relative to sediment sources (Hudson and Askin, 1987).

Major tributaries to the South Saskatchewan River are the Bow, Oldman and Red Deer Rivers and Swift Current Creek. The majority of the river basin, fed by these and smaller tributaries drains agricultural land which is primarily cultivated, with some pasture land.

Figure 5, a pair of stereo aerial photographs taken in 1985, illustrates the river valley and surrounding urbanized terrain in the vicinity of the gauge.

Figure 6, illustrates a profile of the river in the vicinity of the gauge at Saskatoon. The slope of the river in this reach is approximately 0.00024. This figure also indicates that the deep sand bed, which is present throughout the reservoir (Lake Diefenbaker) and downstream of Gardiner Dam, ends at Saskatoon where the river enters a narrow valley having bed and walls formed of shale and glacial till.

The mean annual discharge recorded at the gauging station is 259 m^3/s (period of record 1912 to 1986, inclusive). Flows have ranged from a minimum daily flow of 14.2 m^3/s on December 12, 1936 to a maximum instantaneous flow of 4190 m^3/s recorded on June 15, 1953, as illustrated on Figure 7.

CSMA MR 85A 133

0 500 1000

250 750

Scale (m) approx.

Figure 5 Stereo Aerial Photographs

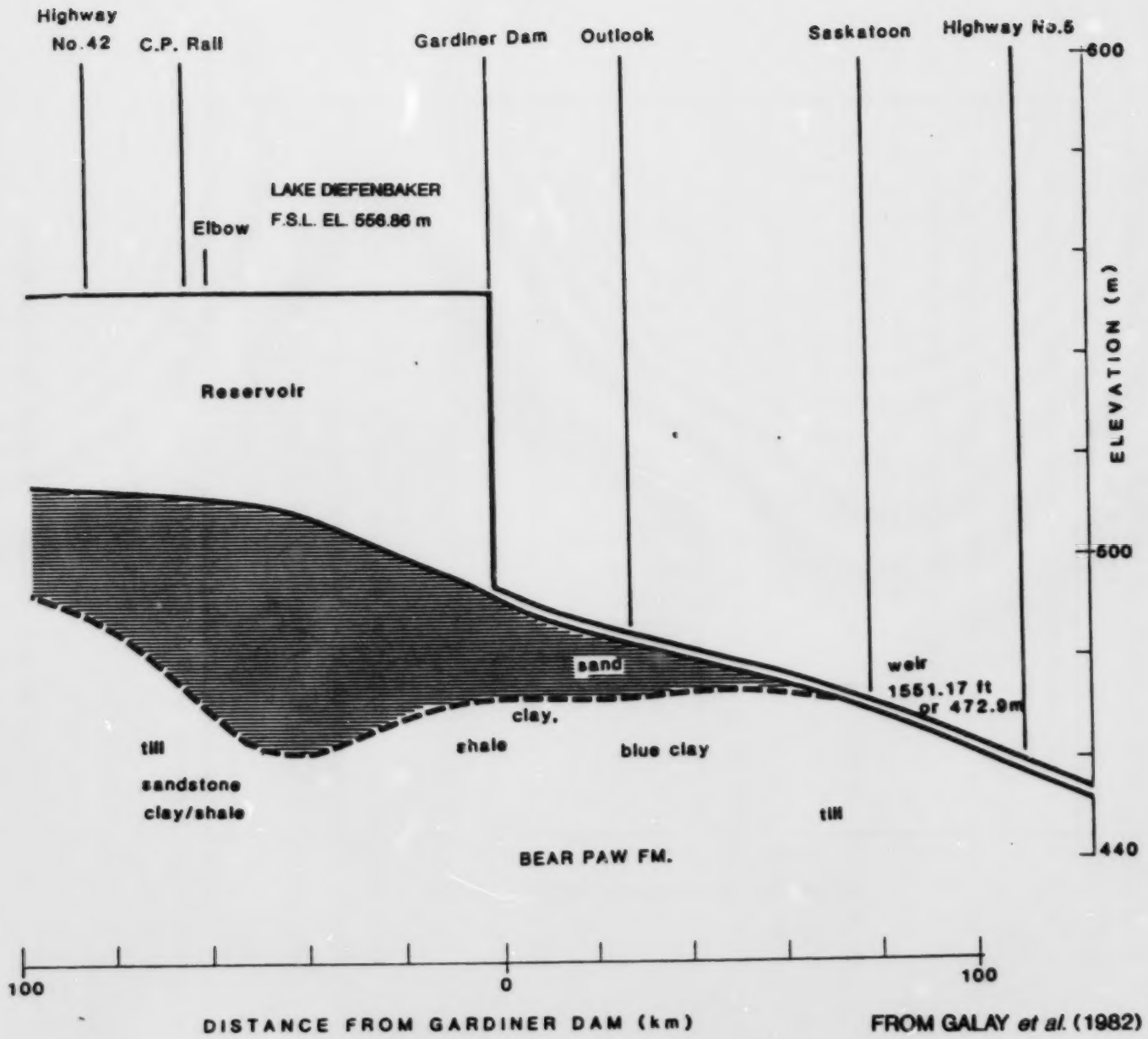


Figure 6 South Saskatchewan River Profile

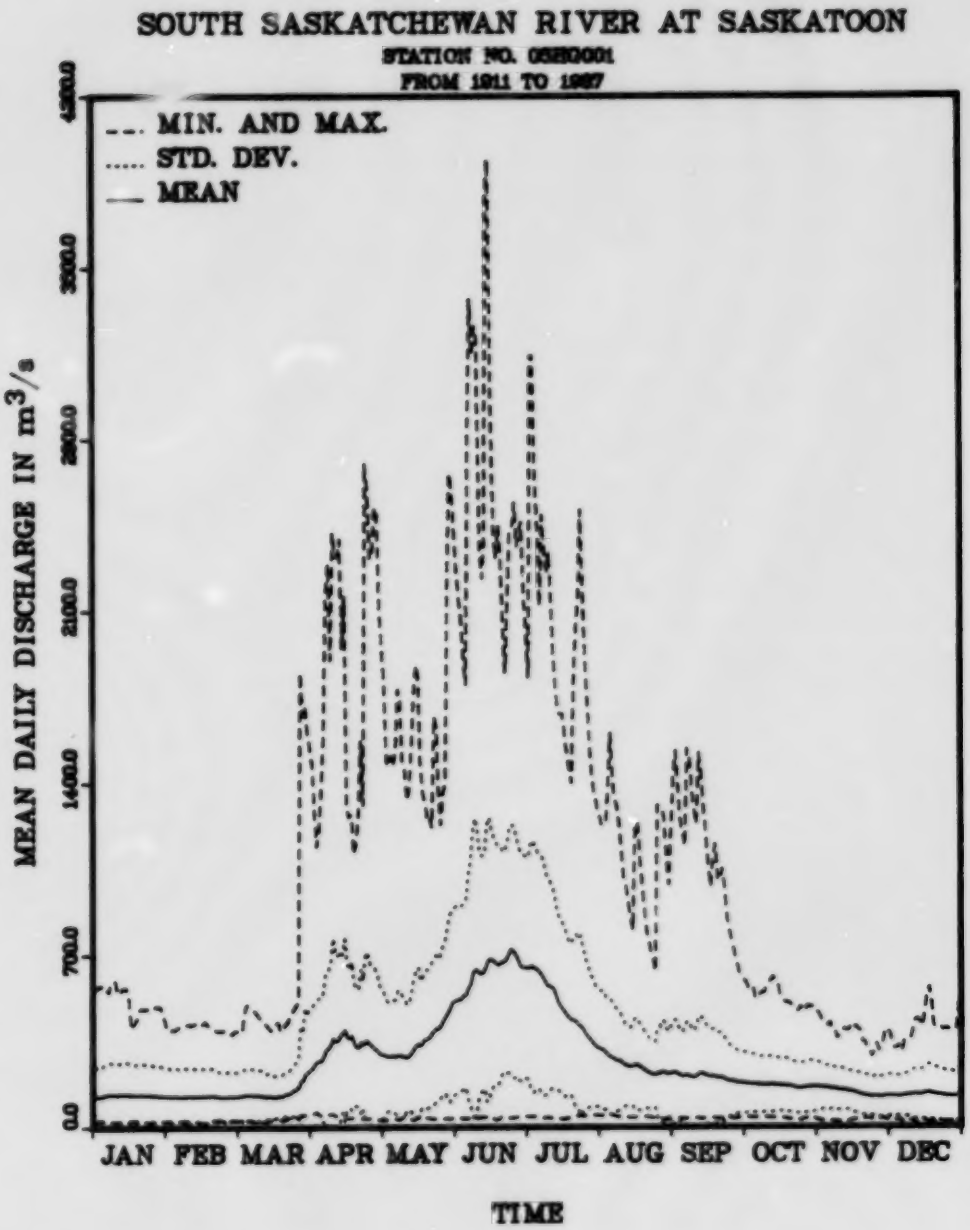


Figure 7 Range of Annual Hydrographs

In 1939-40, the Department of Agriculture, Prairie Farm Rehabilitation Administration constructed a low dam or overflow weir across the South Saskatchewan River at Saskatoon. The purpose of the structure was to improve upstream transportation and water supply intake conditions, as well as to enhance the aesthetic appearance of the stream. The reservoir created by the weir extends an estimated 10 km upstream.

Following construction of the weir, the City of Saskatoon undertook an annual cross-section survey of bed elevations at a number of locations along the reach of river affected by the weir. In 1952, the field surveys were discontinued. Based on the 12-year period of record it is estimated that approximately 1.0 million cubic metres of sediment were deposited in the 10 km reach upstream of the weir. Further data obtained in 1962 indicate that during the period 1952 to 1962, an additional 1.2 million cubic metres of sediment were deposited (Shriek, 1963). However, ongoing river bank development and associated channel in-filling obscures the sedimentation estimates. A comparison of the 1952 and 1979 cross-sections provided in Figure 3 illustrates the extent of the in-filling.

Erosional processes downstream of the weir have not been documented. However, a theoretical assessment has been conducted of the possible impacts of weir removal on the South Saskatchewan River, (Conly and Martz, 1988).

2.3 REACH DESCRIPTION

The gauge location is situated within a straight reach of the channel upstream of the weir, (photographs 1 to 4, and Figures 1 and 5). Measurements are conducted from the Idylwyld (freeway) Bridge, which is situated at the upstream end of a cross-over between bends.

Based upon the photographs in Figure 5, other descriptions of the area contained in National Research Council (1970), and the terms and classification given by Kellerhals *et al.* (1976), a description of the reach containing hydrometric station 05HG001 is presented in Table 1.

3.0 SUSPENDED SEDIMENT DATA

3.1 DATA COLLECTION PROGRAM

Suspended sediment transport data used in this report are summarized in Table 2. For the period under consideration (1961-1971) the data collection has operated on a continuous annual basis, except for 1961 which is considered seasonal as the program commenced in June of that year. Data collected in 1975 was from a short-term miscellaneous program implemented specifically for the June flood event. Daily mean data are available for all years.

Samples were collected mostly at a single vertical, although some sampling was done in multiple verticals (see Section 3.4). A portion of the total sample data used for particle size gradation analyses is listed in Appendix D.

TABLE 1
RIVER VALLEY, VALLEY FLAT AND CHANNEL FEATURES

General Description in Vicinity of Hydrometric Station

Terrain:	plains
Vegetation:	grass
Land Use:	urbanized and mainly cultivated
Surficial Geology:	lacustrine, glacio-fluvial and fluvial deposits

Valley Characteristics Above Valley Flat

Valley measurements within reach and immediate vicinity:

Top width:	2 km
Depth:	15 - 25 m
Bottom width:	100 - 1500 m
Slumping of valley walls:	occasional
Vegetation on valley wall:	sparsely forested and shrubs (deciduous)

Terraces - fragmentary, one level

Relation of Channel to Valley

- streamcut valley, not obviously underfit
- not obviously degrading or aggrading
- frequently confined

Description of Valley Flat

Presence:	fragmentary
Extent:	narrow (<1 water surface width)
Average width:	500 m
Maximum width:	1000 m
Vegetation:	grass and shrubs, mainly built-up

Channel Description

Channel Pattern:	irregular
Islands:	occasional
Type of Flow:	uniform water surface
Bar Type:	mid-channel bars, side bars, large dunes
Natural obstructions:	boulders (lag material)
Degree of obstruction:	occasional, minor

Lateral Channel Activity

Lateral activity:	not detectable
Lateral stability:	stable

Channel Banks and Bed

Alluvial bank material:	silt and sand (non-cohesive), clay and silt (cohesive)
Non-alluvial bank material:	till
Bank vegetation growth:	very strong
Predominant bed material:	sand

TABLE 2
SUMMARY OF SUSPENDED SEDIMENT DATA[1]
(1961 - 1975)

Year	Daily Mean	Monthly Totals and Means[2]	Annual Totals and Means
1961	X	June - December	
1962	X	January - December	X
1963	X	January - December	X
1964	X	January - December	X
1965	X	January - December	X
1966	X	January - December	X
1967	X	January - December	X
1968	X	January - December	X
1969	X	January - December	X
1970	X	January - December	X
1971	X	January - December	X
1975		June[3]	

NOTES:

1. Suspended sediment data is available from Water Resources Branch, Environment Canada, Regina for 1961-1971 and 1975.
2. Refers to months (inclusive) where continuous daily records are available and where means and totals are published.
3. Miscellaneous data only for 2 sampled days in this month.

3.2 SAMPLING STRATEGIES

The sediment sampling program was initiated on June 24, 1961 following the mountain snowmelt runoff peak. A continuous annual sampling program was followed until December 31, 1971, when the program was essentially terminated.

Samples were collected on a flow-weighted basis, which resulted in more samples being taken during high flows and fewer during the recession period of the annual flow hydrographs, (Table 3).

3.3 SAMPLING EQUIPMENT AND PROCEDURES

During the sediment sampling program, two sediment sampling stations were used. The first was situated on the Traffic Bridge. Later it was moved to the catamaran boat measurement site, about 800 m below the gauge, or 700 m below the weir. The miscellaneous measurements in 1975 were conducted from the Idylwyld (freeway) Bridge.

Sampling at low stages was conducted using a DH-48 sampler, while at high stages a D-49 sampler was used. Miscellaneous point-integrating samples were gathered with a point-integrating sampler. Small (3.18 mm ID or 1/8 inch), medium (4.76 mm or 3/16 inch), or large (6.35 mm or 1/4 inch) brass nozzles were used.

A note in W.S.C. files regarding the two miscellaneous sediment measurements in 1975 indicates that "both sediment measurements gave unsatisfactory results and were not used. The wrong type of sampler was

TABLE 3

SUMMARY OF SUSPENDED SEDIMENT SAMPLING PROGRAM SHOWING NUMBER OF SAMPLED DAYS EACH MONTH

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	-	-	-	-	-	7	27	14	7	6	1	2	64
1962	1	2	1	15	17	22	19	16	10	4	4	2	113
1963	2	2	5	29	18	18	28	26	14	6	5	3	139
1964	2	2	1	20	25	25	18	9	6	4	4	2	118
1965	2	2	1	7	8	19	23	15	16	11	1	2	107
1966	1	1	5	15	14	26	23	5	4	4	1	2	101
1967	8	3	2	4	10	18	15	3	4	3	3	2	75
1968	2	2	2	2	2	2	4	3	1	3	4	2	29
1969	2	2	4	10	13	3	26	10	8	8	4	0	90
1970	1	0	4	7	7	12	12	12	12	12	6	0	85
1971	1	2	3	4	7	9	19	8	4	2	2	2	63
1975	-	-	-	-	-	2	-	-	-	-	-	-	2
Total	22	18	28	113	121	173	212	109	78	62	33	17	986
Mean	2.2	1.8	2.8	11.3	12.1	14.4	19.3	9.9	7.1	5.6	3.0	1.5	82.2
Standard Deviation	2.10	0.79	1.62	8.49	6.71	9.77	6.96	4.74	4.25	3.32	1.61	0.82	38.74

used for this type of velocity as the sampler was not reaching the proper depth but was riding on the surface."

3.4 SINGLE VERTICAL AND MULTIPLE VERTICAL SAMPLES

The bulk of suspended sediment samples were taken as depth-integrated single vertical samples collected at the sampling station. These samples were taken by W.S.C. technicians and a paid local observer.

The remaining suspended sediment samples were collected during the performance of cross-sectional suspended sediment discharge measurements by W.S.C. technicians. Five verticals were sampled and located at the mid-point of equal 20% streamflow discharge panels. These measurements were used to determine a cross-sectional average concentration. This value, in turn, is used with the concentration of the single vertical data (commonly referred to as the daily data) to arrive at a coefficient (K factor) used to adjust the single vertical data to cross-sectional averages. Appendix C presents data on K factors from 1961 to 1971. From the 97 measurements, the mean K is 1.02, with the extreme values 0.71 and 1.8. This range is larger than desirable, (standard deviation = 0.42), and may be due to contamination of samples which produces high concentrations or errors in laboratory and computational analyses; (K values as low as 0.50 and as high as 5.0 have been calculated). Further investigation and quality control checks of the existing data base are advisable.

The K-factor data in Appendic C also indicates that point-integrating sample results are comparable to those from depth integrating samples for those dates when duplicate results exist.

3.5 SAMPLE COVERAGE OF FLOWS

For the period 1961-1971, the minimum sampled annual discharge (daily mean) was 28.1 m^3/s (December 1, 1966) which was equalled or exceeded 99% of the time, (a flow duration curve is shown in Figure 8). The maximum sampled annual discharge (daily mean) was 1780 m^3/s (July 6, 1969, 1180 mg/L) which was equalled or exceeded less than 1% of the time. The maximum instantaneous discharge which occurred during the sediment program was 1790 m^3/s. This occurred on June 26, 1975, between the two miscellaneous measurements gathered that year.

Sample coverage of events and annual hydrographs is generally good because of the flow-weighted sampling strategy.

3.6 REPRESENTATIVITY OF THE SEDIMENT DATA RECORD

The period of hydrometric record (1911 - 1987) contains and extends beyond the period of sediment sampling (1961 - 1971, 1975) for the South Saskatchewan River at Saskatoon. Therefore, the representativity of the sediment data record may be assessed by relating the flows covered during the sediment program to the overall hydrometric program.

For example, frequency analyses of annual maximum daily mean discharges for the South Saskatchewan River at Saskatoon is indicated in Figure 9. The position of each year of the sediment program is indicated on the plots. The

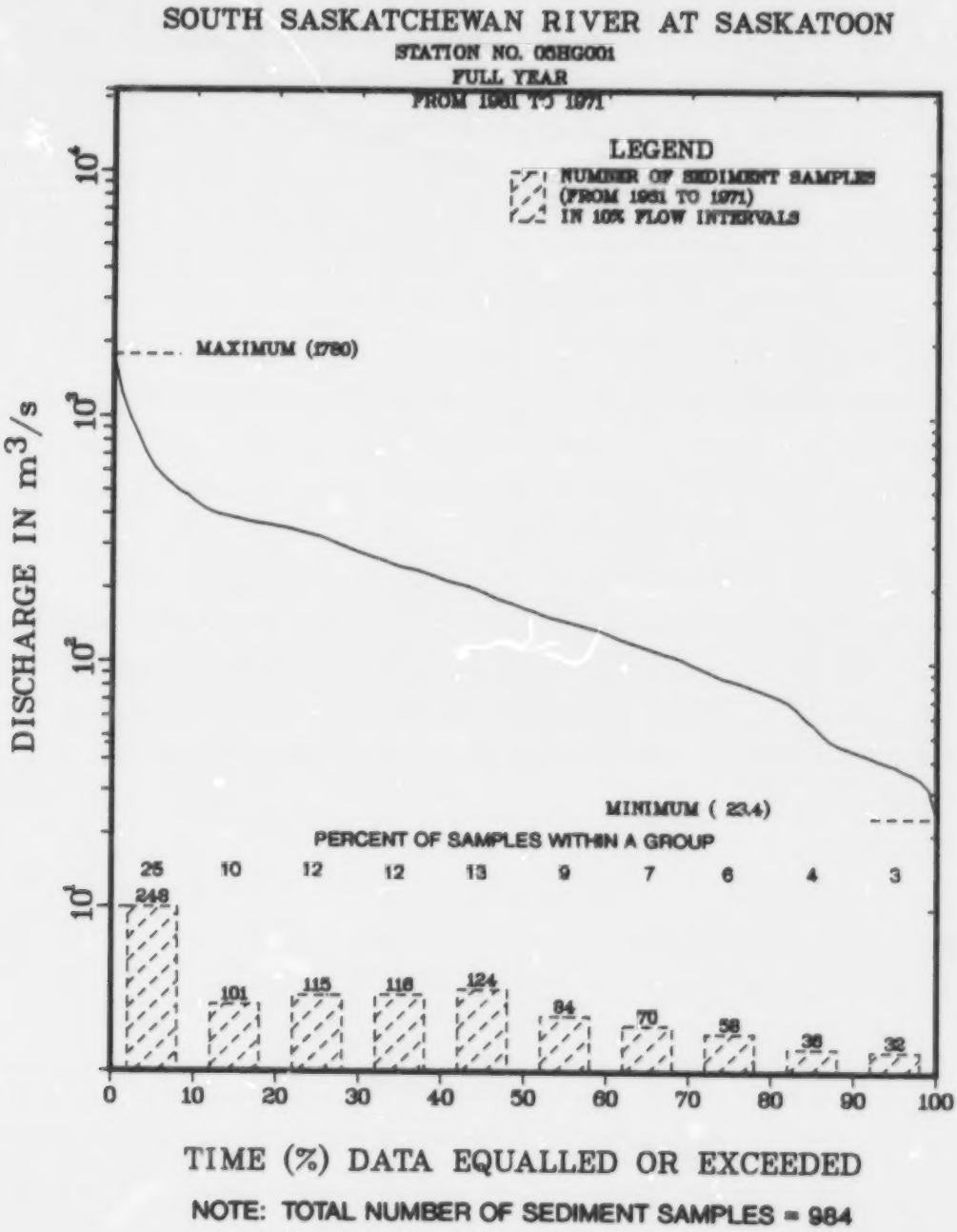

SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
FULL YEAR
FROM 1961 TO 1971
LEGEND
NUMBER OF SEDIMENT SAMPLES
(FROM 1961 TO 1971)
IN 10% FLOW INTERVALS
MAXIMUM (1780)
MINIMUM (234)
DISCHARGE IN m3/s
PERCENT OF SAMPLES WITHIN A GROUP
25 10 12 12 13 9 7 6 4 3
248 101 115 116 124 84 70 58 36 32
0 10 20 30 40 50 60 70 80 90 100
TIME (%) DATA EQUALLED OR EXCEEDED
NOTE: TOTAL NUMBER OF SEDIMENT SAMPLES = 984

Figure 8 Flow Duration Curve

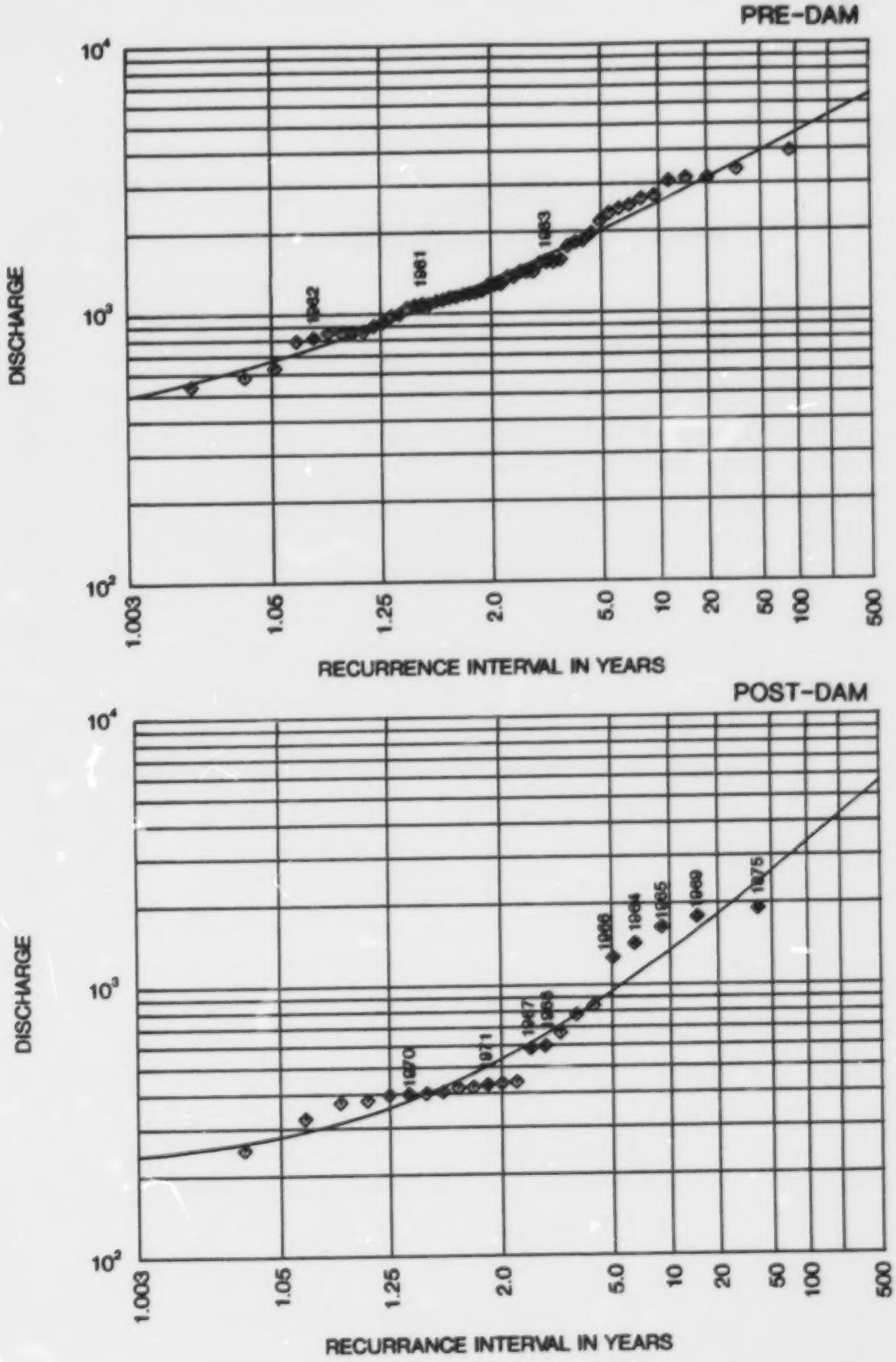


Figure 9 Frequency Plot of Annual Maximum Daily Discharges

pre-dam plot indicates the coverage is poor, with only a narrow band of near-median flows covered by the 3 years of data. Coverage during the post-dam period is much better, and includes the higher end of the flow spectrum. As a significant proportion of the total suspended load is transported during short periods of high flow (see Section 4.2), it is important that these periods are sampled across a good range.

Similarly, a frequency plot of annual total discharge data for the South Saskatchewan River at Saskatoon (Figure 10), indicates that the period of the sediment program is generally representative of longer term conditions, although the high end of the flow spectrum (upper 15%) is not covered.

An additional method for assessing the representativeness of the sediment program at Sta. 05HG001 is presented in Figure 11, where the annual mean and maximum discharges are plotted against the years of record. These data indicate that the sediment program has operated during a period when both annual maximum and mean discharge have varied randomly about their means. Figure 11 also shows a plot of the accumulated departures for the annual mean total load and discharge for the period 1961 to 1971 and 1911 to 1986, respectively. Years with annual loads (or discharges) greater than the mean are shown as increases; those less than the mean are shown as decreases. It is important to note how the load and discharge curves parallel each other, indicating a strong correlation (see discussion, Section 4.2).

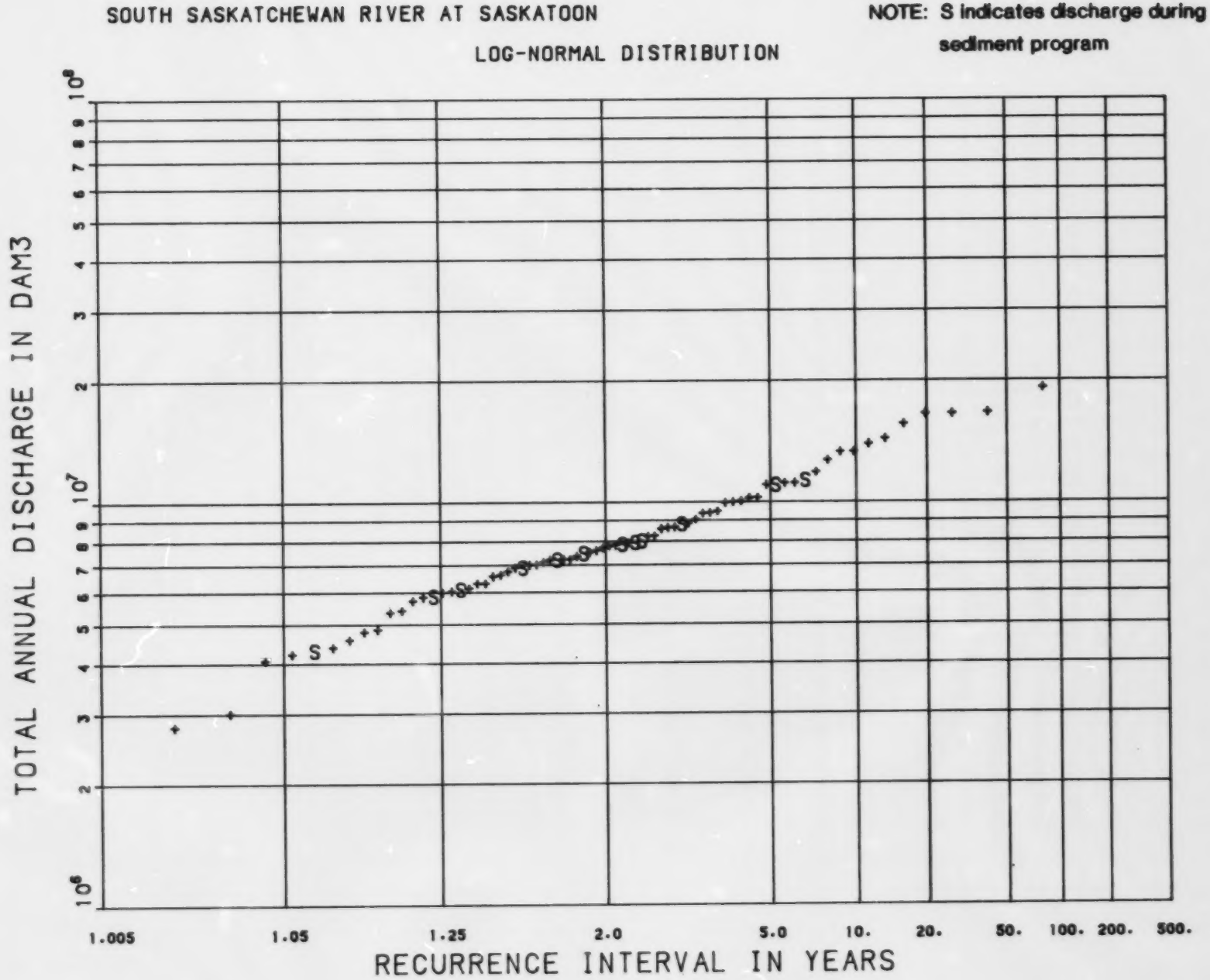


Figure 10 Frequency Plot of Total Annual Discharges

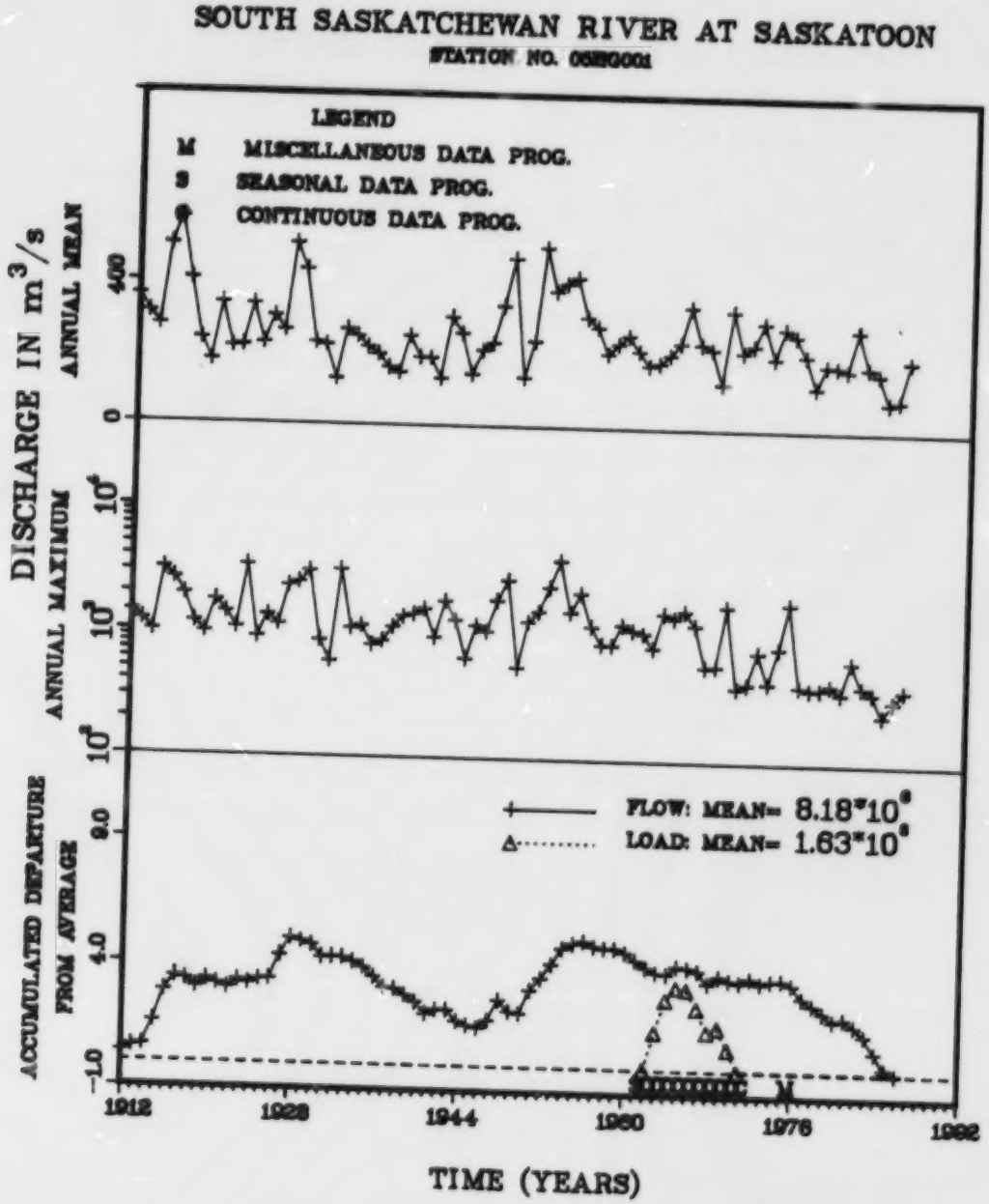


Figure 11 Flow History During the Sediment Sampling Program

4.0 SUSPENDED SEDIMENT TRANSPORT REGIME

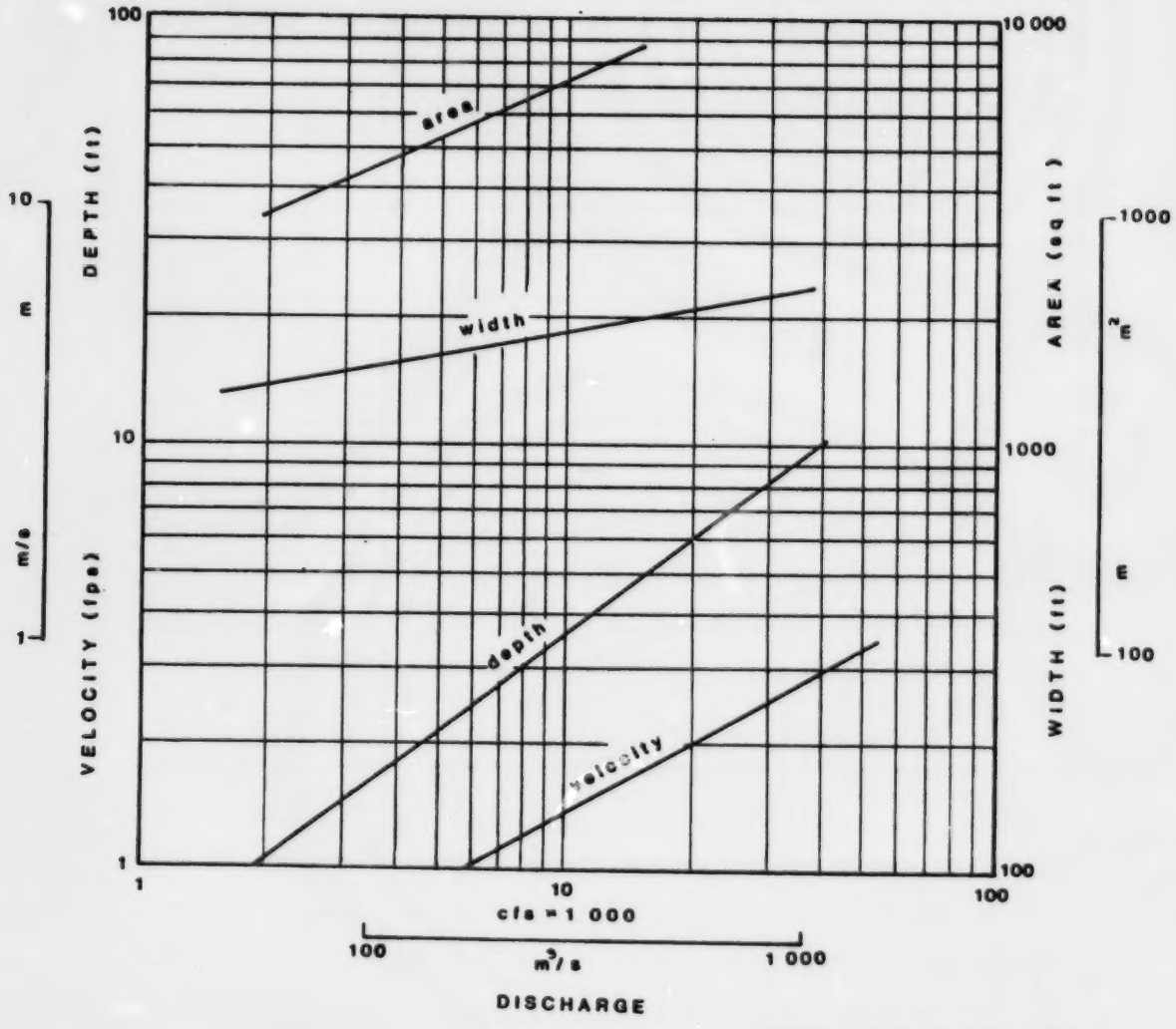
4.1 SUPPLEMENTARY DATA

4.1.1 Hydraulic Data

Mean cross-sectional hydraulic data (area, mean velocity, surface width, and mean depth) derived from measurements between Gardiner Dam and Outlook are illustrated in Figure 12. The reliability of the relationships inferred by Figure 12 in defining at-a-station hydraulic properties is difficult to determine as data points are not indicated. Hydraulic data representative of the reach at the hydrometric station are not readily available, and would be affected by the operation of the weir.

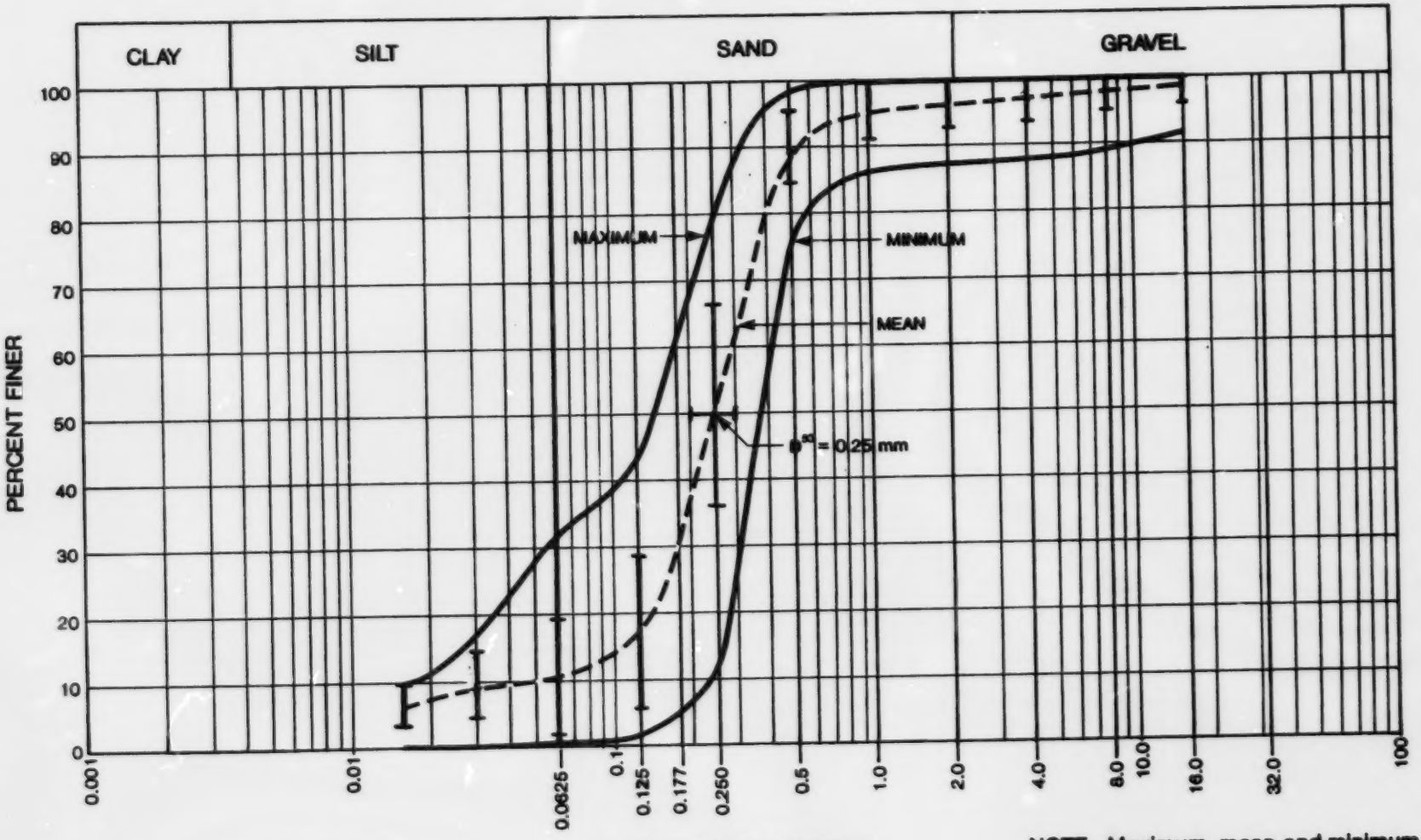
4.1.2 Bed Material Data

A total of 26 bed material samples have been gathered on the South Saskatchewan River at Saskatoon between 1961 and 1971. Sampling sites were located at the Traffic Bridge. Mean characteristics of the bed material are summarized in Table 4 and Figure 13.



FROM GALAY *et al.* (1982)

Figure 12 Hydraulic Data



NOTE: Maximum, mean and minimum refer to percent passing for a particular size

Figure 13 Bed Material Summary

TABLE 4

MEAN BED MATERIAL CHARACTERISTICS

Percent Passing	Size (mm)
100	32
90	0.5
84	0.43
65	0.31
50	0.247
16	0.12

Grading = (D_{84}/D_{16}) ** 0.5 = 1.93

Table 5 presents the data in its entirety.

The bed material at Saskatoon appears to be primarily sand (85%) with lesser amounts of gravel (4%) and silt and clay (11%). The above W.S.C. data agrees closely with data used by Conly and Martz (1988) and Ashmore *et al.* (1988)

As noted in Table 5, Lane and BM-54 samplers have been used to gather bed material samples; sampler type is not specified for 11 of the samples. The BM-54 sampler gathered samples with smaller mean material size (D_{50} = 0.258 mm) than the Lane (0.274 mm) sampler. The samples from the BM-54 sampler are close to the overall mean D_{50} for the bed material (0.247 mm).

TABLE 5

PARTICLE SIZE ANALYSIS OF BED MATERIAL

SOUTH SASKATCHEWAN RIVER AT SASKATOON — **STATION NO. 05HG001**

PARTICLE SIZE ANALYSIS OF BED MATERIAL

Date	Points	Percent Finer Than Indicated Size, in millimetres												Total		Type of Sampler
		0.016	0.031	0.062	0.125	0.25	0.50	1.00	2.00	4.00	8.00	16.0	32.0	64.0	D50	GDG	
Oct.6, 1961	6				32	43	65	94	97	98	99	100			0.164	*	N/A
May 8, 1962	9			14	20	48	90	96	98	99	100				0.258	2.2	N/A
June 19, 1962	10			12	29	60	93	97	98	100					0.207	2.3	N/A
Sept. 4, 1962	6			08	17	53	80	90	95	98	100				0.239	2.4	N/A
Dec. 6, 1962	8				17	63	91	100							0.209	*	N/A
Mar. 26, 1963	8			04	18	60	96	100							0.220	1.7	N/A
Apr. 18, 1963	9			19	28	54	84	90	96	98	100				0.231	*	N/A
May 18, 1963	7	03	05	11	20	50	93	97	98	99	100				0.250	2.1	N/A
Jun. 21, 1963	8	09	12	19	28	63	87	89	91	92	96	99			0.207	2.8	N/A
Jul. 9, 1963	9	07	12	18	30	60	89	93	94	95	98	100			0.207	2.9	N/A
Aug. 7, 1963	8		17	23	33	52	88	91	92	93	96	100			0.238	*	N/A
Oct. 9, 1963	5		12	18	28	53	89	94	97	98	100				0.236	2.9	BM-54
Nov. 8, 1963	5			03	11	60	97	100							0.226	1.5	LANE
Feb. 25, 1964	4		10	11	26	79	99	100							0.179	1.7	LANE
May 13, 1964	5			02	09	55	94	97	98	99	100				0.237	1.6	BM-54
Jun. 17, 1964	5			01	02	28	78	87	92	96	98	100			0.336	1.8	BM-54
Oct. 19, 1964	4		04	06	12	48	90	95	97	98	100				0.257	1.7	BM-54
Apr. 29, 1965	10		03	07	21	50	81	86	87	88	89	92			0.250	2.4	LANE
May 11, 9165	7			08	23	64	96	99	100						0.207	1.9	BM-54
Jun. 25, 1965	4				03	53	94	99	100						0.241	1.6	BM-54
Sep. 1, 1965	4				02	11	85	94	98	100					0.376	1.3	LANE
Nov. 8, 1965	2				01	18	81	92	94	96	98	99			0.369	1.5	LANE
Mar. 14, 1966	4			01	08	58	96	100	100	100					0.231	1.5	LANE
Apr. 8, 1966	5			00	05	57	93	94	94	94	95	98			0.230	1.6	LANE
Jun. 16, 1971	5				02	39	92	99	99	100					0.289	1.6	BM-54
Jul. 21, 1971	3			01	05	28	89	99	100						0.330	1.5	LANE

GDG (Grading) = Square Root (D84/D16)
* - Unable to Compute due to Insufficient Data
N/A - Not Available

4.1.3 Dissolved Solids Data

Information on dissolved solids is available for 1961 to 1970. These data are, in part, a by-product of certain analyses (evaporation, particle size distribution) and in part, a general program objective to collect such data. All dissolved load data are included as annual diagrams in Appendix B.

4.2 TIME DISTRIBUTION OF SEDIMENT LOAD

Suspended sediment transport is strongly seasonal with most of the load being transported during the rise to peak discharge period (March-May). This pattern is well illustrated in hydrographs of daily mean discharge, concentration and loading, as in Figure 14 for 1962 (pre-dam) and 1969 (post-dam). Note the location of samples on these hydrographs denoted by the 's'. Similar hydrographs for the remaining years of record are contained in Appendix E.

One method of displaying the significance of short duration transport events is given in Figure 15, where suspended sediment load for 1% and 10% of the annual period (i.e. 4, and 37 consecutive days of the 365-day annual period) are compared with the total annual load. These data are also presented in Table 6. Clearly much of the annual load is transported in 10% of the time. In some years, particularly 1969, a significant proportion is transported within one day. Furthermore these data illustrate that infrequent, large magnitude transport events (e.g. 1963) can transport more sediment in one day than are transported in total over several years.

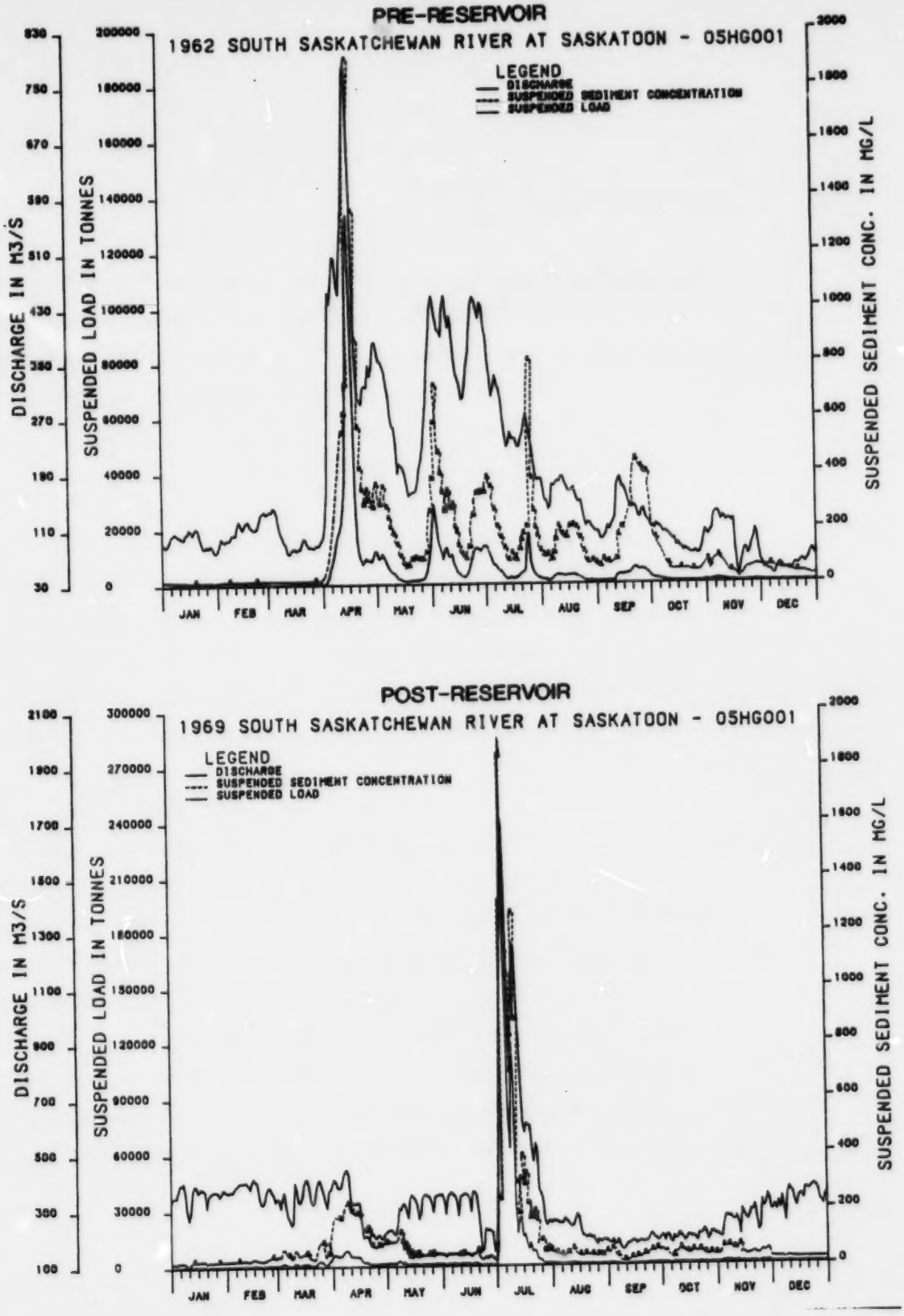

PRE-RESERVOIR
1962 SOUTH SASKATCHEWAN RIVER AT SASKATOON - 05HG001
LEGEND
DISCHARGE
SUSPENDED SEDIMENT CONCENTRATION
SUSPENDED LOAD
DISCHARGE IN M3/S
SUSPENDED LOAD IN TONNES
SUSPENDED SEDIMENT CONC. IN MG/L
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
POST-RESERVOIR
1969 SOUTH SASKATCHEWAN RIVER AT SASKATOON - 05HG001
LEGEND
DISCHARGE
SUSPENDED SEDIMENT CONCENTRATION
SUSPENDED LOAD
DISCHARGE IN M3/S
SUSPENDED LOAD IN TONNES
SUSPENDED SEDIMENT CONC. IN MG/L
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Figure 14 Annual Distribution of Daily Mean Suspended Sediment Concentration, Load and Water Discharge for 1962 and 1969

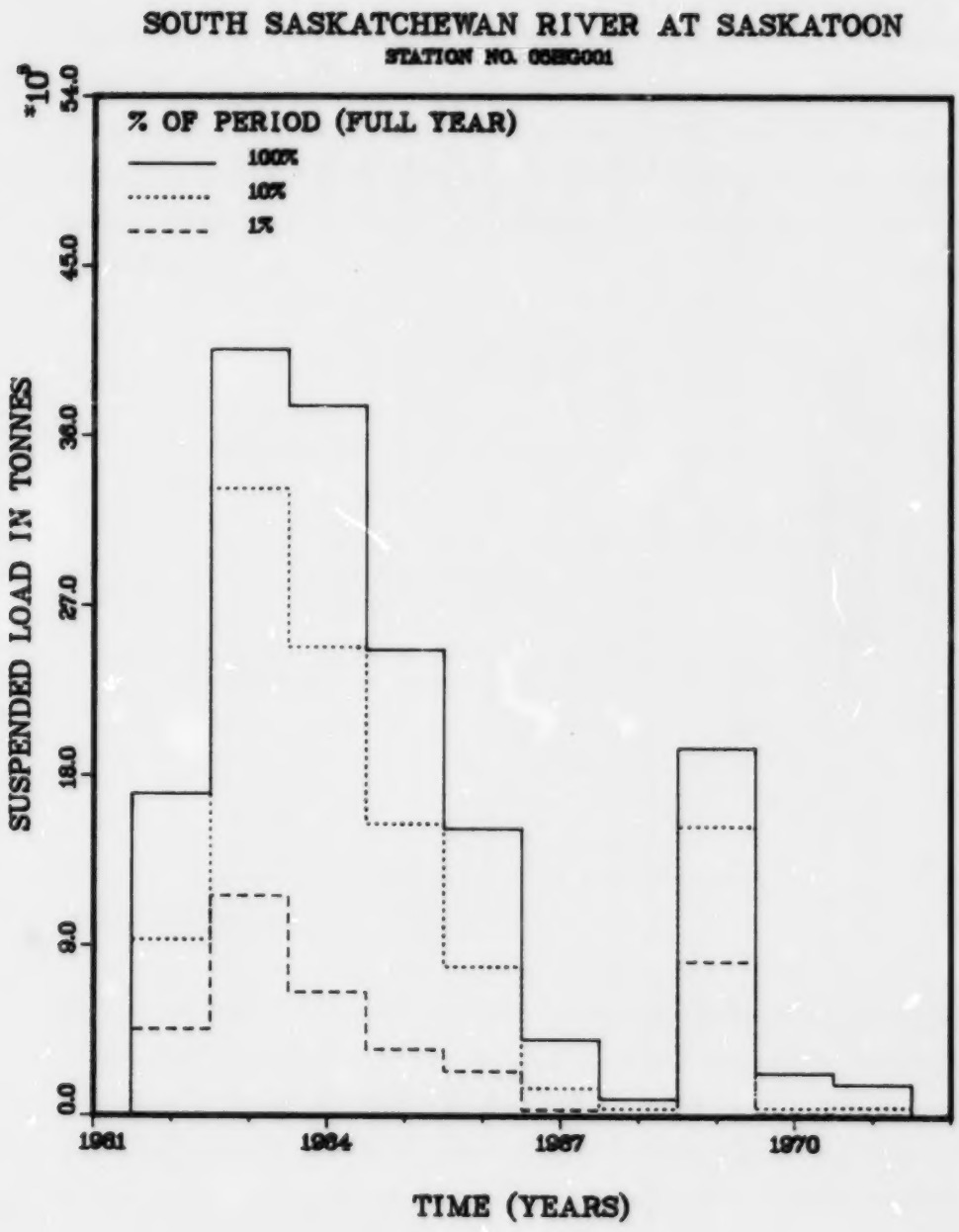


Figure 15 Percentage of Load Transported During Events of 1, 10, and 100% of the Total Time Period

TABLE 6

DISTRIBUTION OF SHORT - DURATION EVENTS TO ANNUAL SEDIMENT LOAD SOUTH SASKATCHEWAN RIVER AT SASKATOON (LOAD IN TONNES)

Year	Total Period	Best Day			Best 1%			Best 10%		
	Load (A)	Date of Max. (B)	Load (C)	% of Column (A) (D)	Starting Date (E)	Load (F)	% of Column (A) (G)	Starting Date (H)	Load (I)	% of Column (A) (J)
1962	1 702 183	April 16	139 000	8.2	April 14	455 900	26.8	April 4	928 960	54.6
1963	4 055 339	July 8	323 000	8.0	July 7	1 161 000	28.6	June 17	3 317 700	81.8
1964	3 756 688	June 18	198 000	5.3	June 17	653 000	17.4	May 27	2 479 580	66.0
1965	2 464 446	June 27	98 600	4.0	June 26	349 600	14.2	June 19	1 542 500	62.6
1966	1 517 460	June 13	67 000	4.4	June 10	235 400	15.5	May 17	787 130	51.9
1967	404 058	July 5	10 900	2.7	July 4	33 750	8.4	June 17	146 689	36.3
1968	91 917	November 3	2 500	2.7	November 2	7 970	8.7	October 11	39 863	43.4
1969	1 946 030	July 5	293 000	15.1	July 4	818 000	42.0	July 1	1 531 734	78.7
1970	228 742	June 25	3 540	1.5	June 22	13 770	6.0	January 26	44 160	19.3
1971	170 317	June 16	2 960	1.7	June 14	10 780	6.3	May 21	49 024	28.8

Figure 16 illustrates an alternative means of examining short-term suspended sediment transport, by replacing the ordinate of the suspended sediment load duration curve by the cumulative percentage of the total load transported during the period of record plotted on a probability scale, beginning with the highest daily load. Figure 16 indicates the cumulative load durations presented in Table 7.

TABLE 7

CUMULATIVE LOAD DURATIONS

Time	Cumulative Percent of Total Suspended Sediment Load Carried in Time Interval Load
0.1%	8%
1.0%	40%
5.0%	77%

4.2.1 Effective Discharge

The importance of relatively infrequent events in transporting the majority of the total suspended sediment load may also be examined by determining the range of flows which carries the greatest amount of sediment over a period of several years. While the larger magnitude events may carry more sediment than the small but more frequent events, these extreme events may

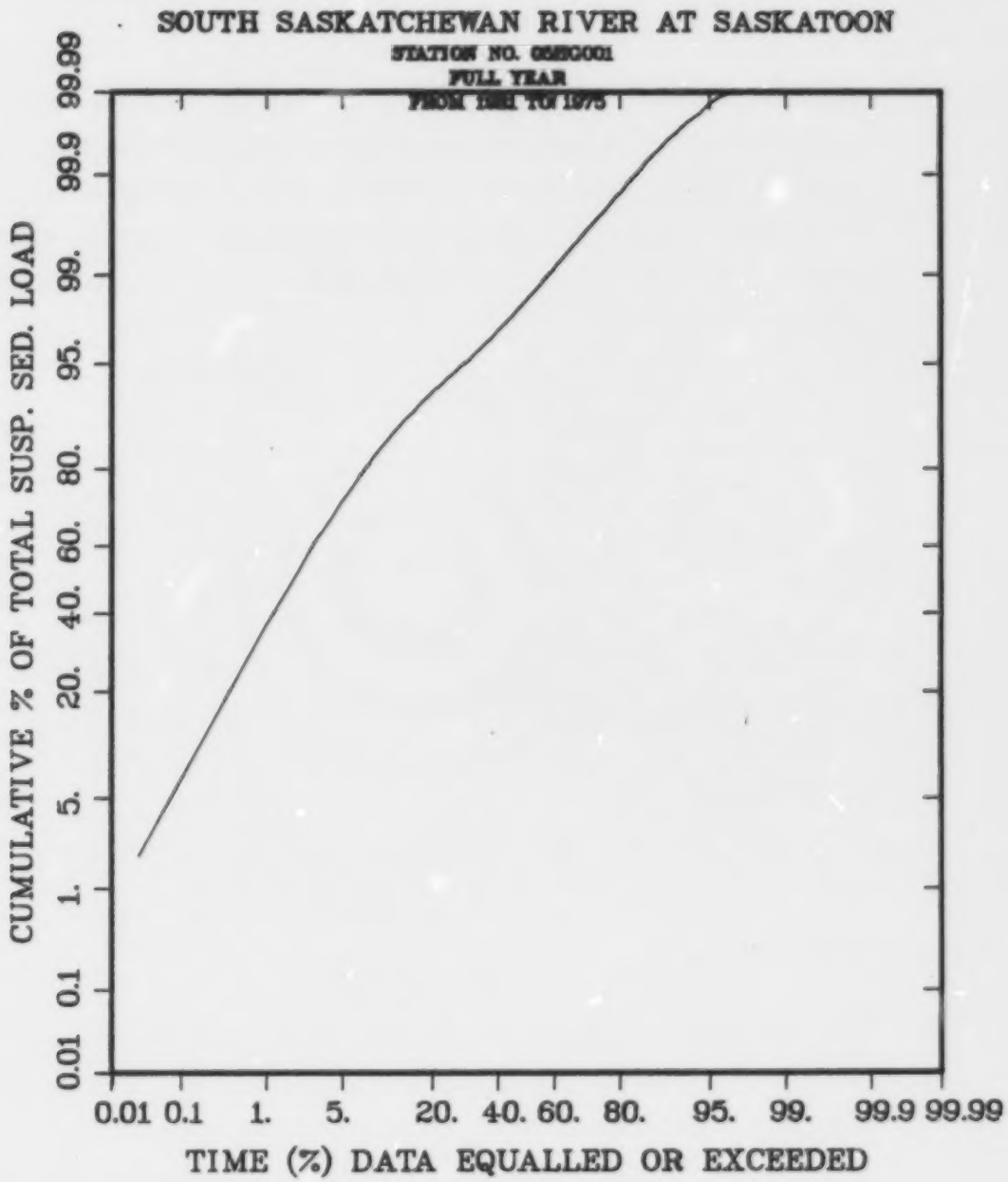

SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05EC001
FULL YEAR
FROM 1961 TO 1975
CUMULATIVE % OF TOTAL SUSP. SED. LOAD
0.01 0.1 1. 5. 20. 40. 60. 80. 95. 99. 99.9 99.99
0.01 0.1 1. 5. 20. 40. 60. 80. 95. 99. 99.9 99.99
TIME (%) DATA EQUALLED OR EXCEEDED

Figure 16 Cumulative Load Duration Curve

be too few and far between to be significant. The parameter used to illustrate this phenomenon is the "effective" discharge, or the discharge which is most significant for sediment transport over the long term. It is the increment of discharge with the highest corresponding total load.

The effective discharge plot for the Saskatoon station on the South Saskatchewan River is presented in Figure 17. The upper half of this plot indicates the total load transported over the period of record by flows within each discharge increment. The frequency distribution of these flows appears in the lower half of the diagram.

Data taken from Figure 17 indicates that the effective discharge falls within two ranges: 333 to 500 m^3/s, and 1167 to 1333 m^3/s which have occurred for 635 and 27 days or 17% and 1% of the sediment sampling period, respectively.

4.2.2 Load and Discharge Relationships

The association of suspended sediment load to discharge is shown in Figure 18 for annual flows. The strong association commonly observed on natural streams appears less distinctive here, probably due to the influence of Gardiner Dam (see Section 5.2). The importance of short-duration events in transporting large volumes of sediment may also affect the relationship. It should be noted from Figure 18 that there is a greater variability in the annual suspended sediment loads, (C_v = 0.89) than in the annual flow volumes, (C_v = 0.27). Figure 19 illustrates the flow and load relationships for monthly data. Arranging the same data into a rating curve format results in Figure 20 for monthly mean concentrations and loads. It

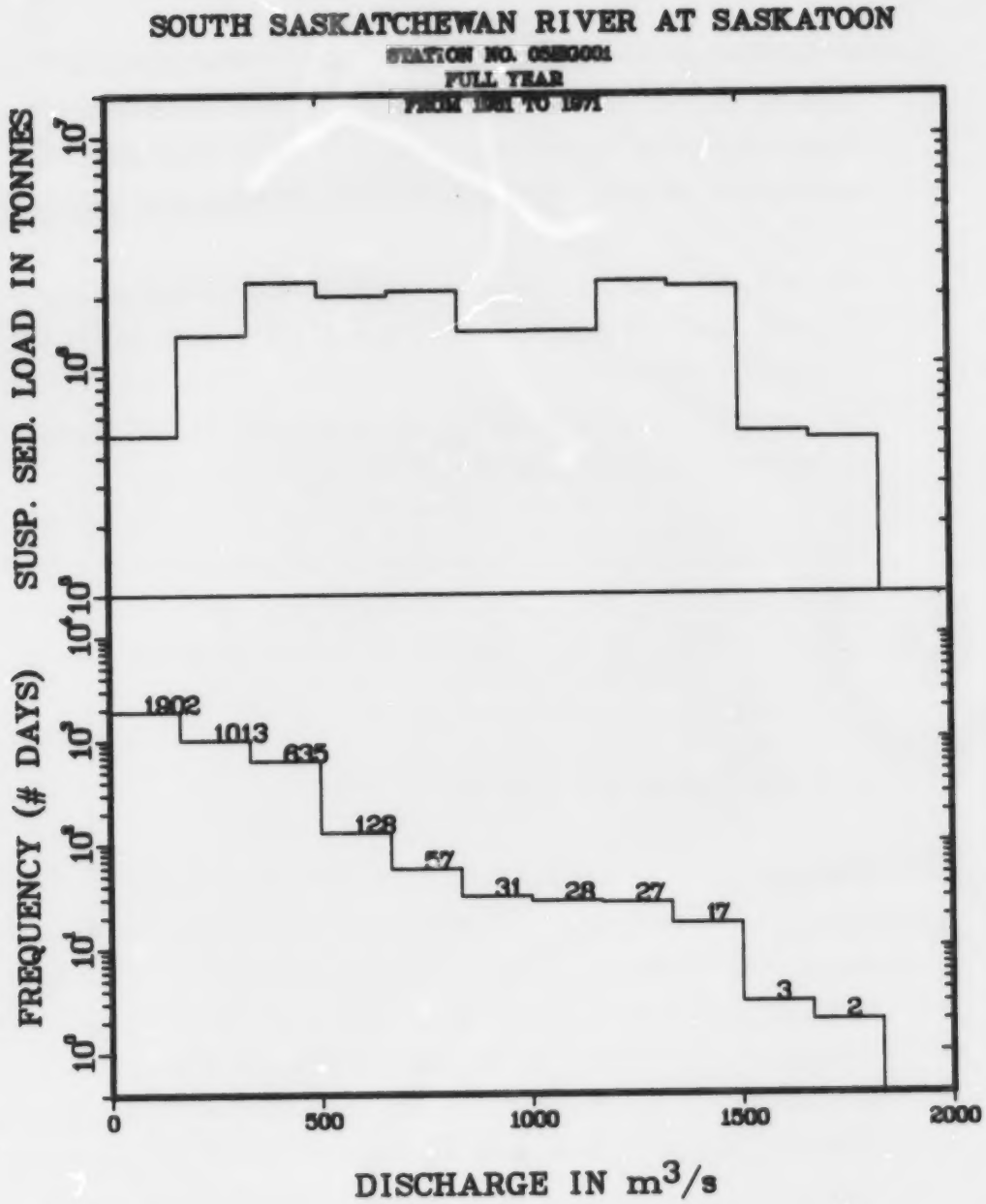


Figure 17 Effective Discharge Plot

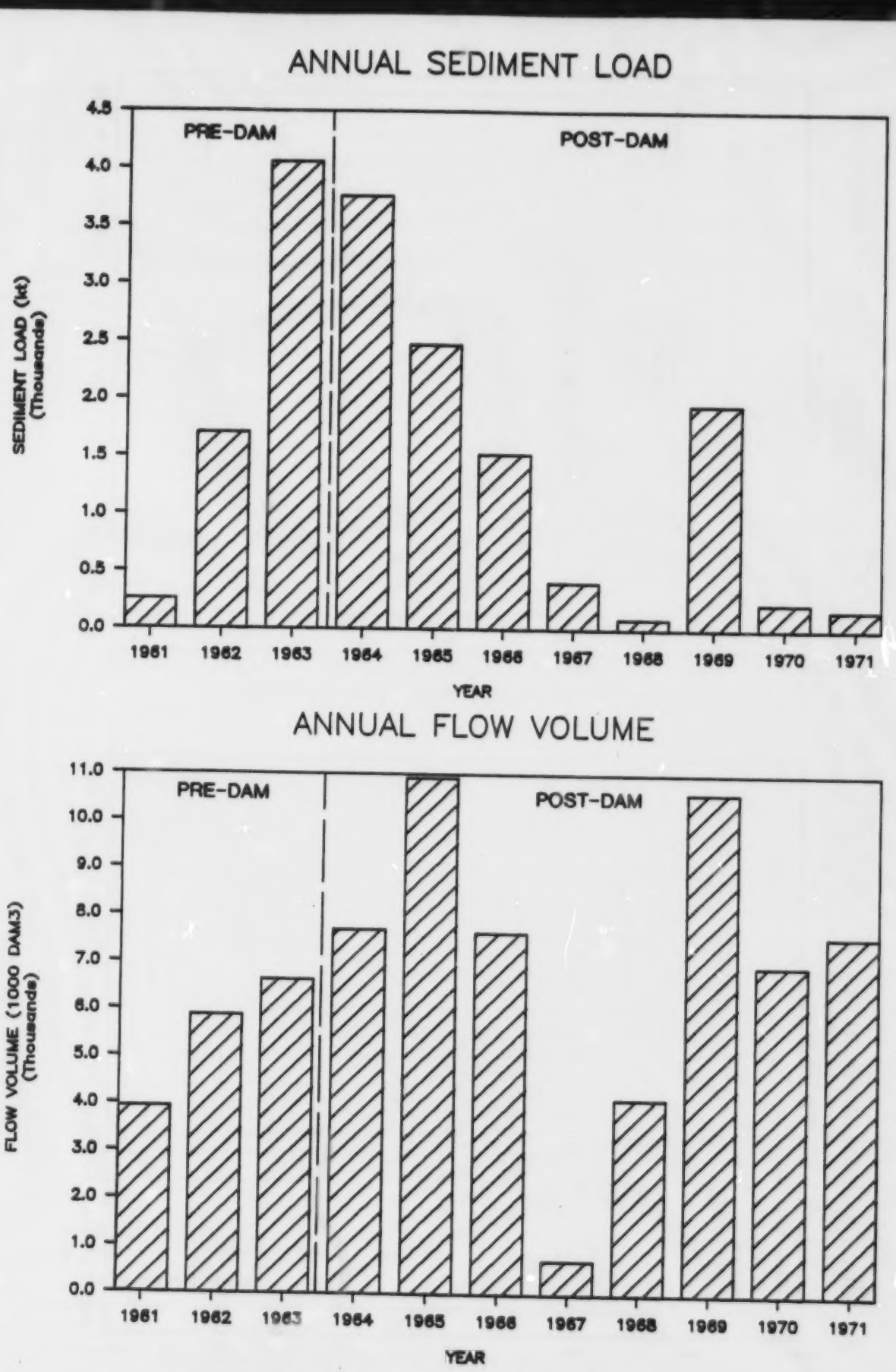
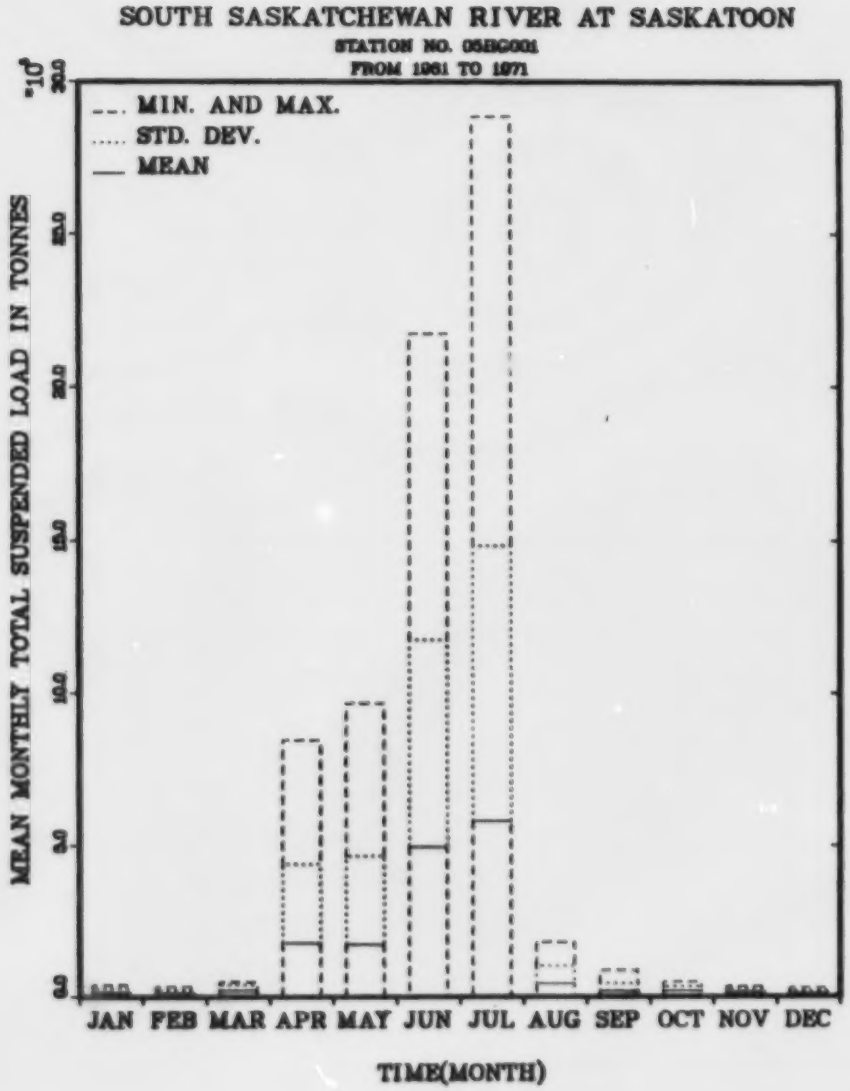


Figure 18 Annual Sediment Loads and Flow Volumes


SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HC001
FROM 1961 TO 1971
--- MIN. AND MAX.
..... STD. DEV.
___ MEAN
MEAN MONTHLY TOTAL SUSPENDED LOAD IN TONNES
*10³
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
TIME(MONTH)

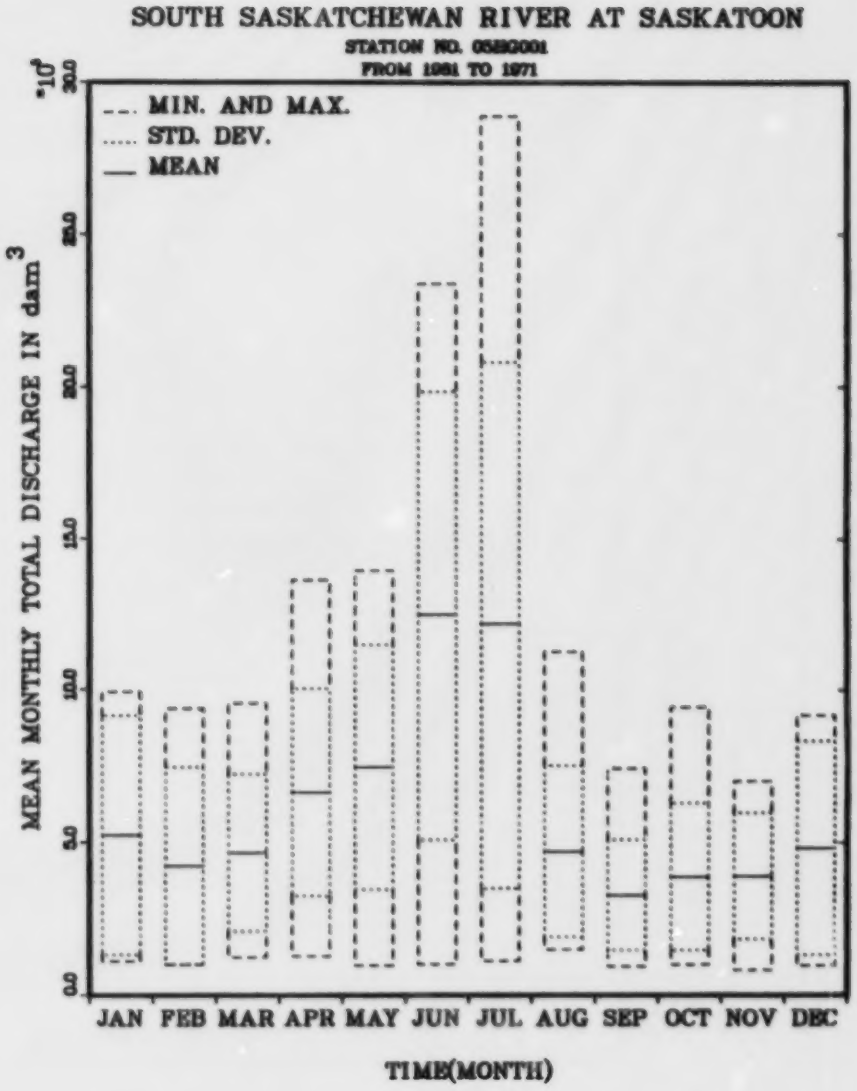
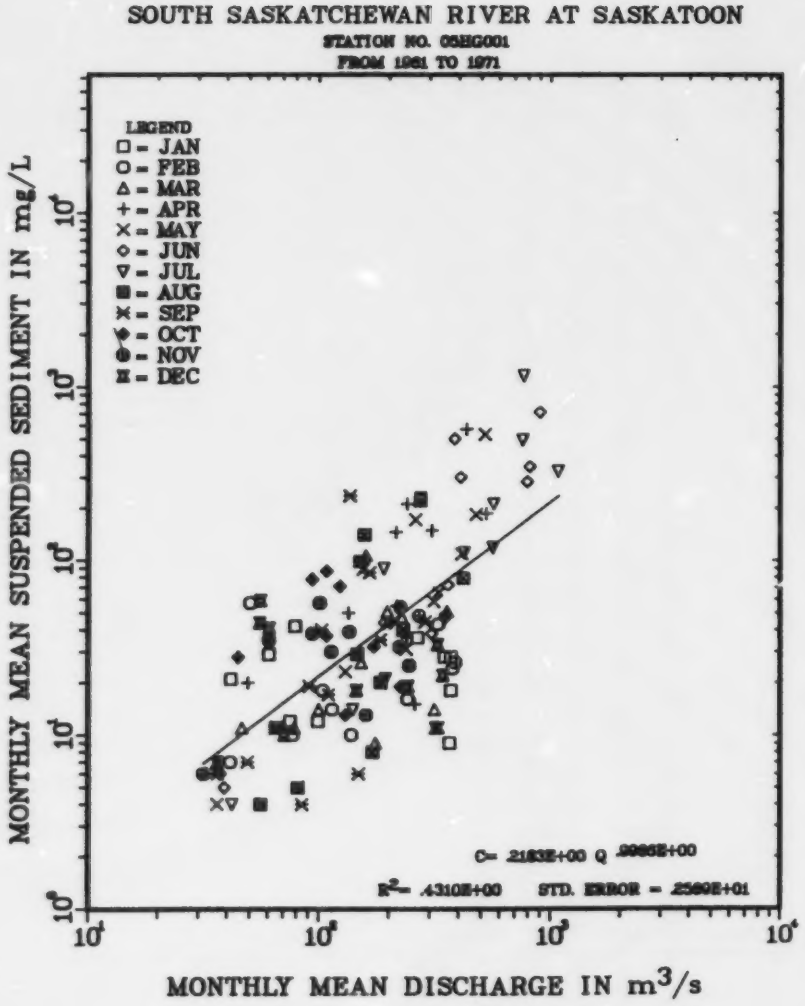

SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HC001
FROM 1961 TO 1971
--- MIN. AND MAX.
..... STD. DEV.
___ MEAN
MEAN MONTHLY TOTAL DISCHARGE IN dam³
*10³
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
TIME(MONTH)

Figure 19 Mean Monthly Distribution of Suspended Sediment Load and Discharge



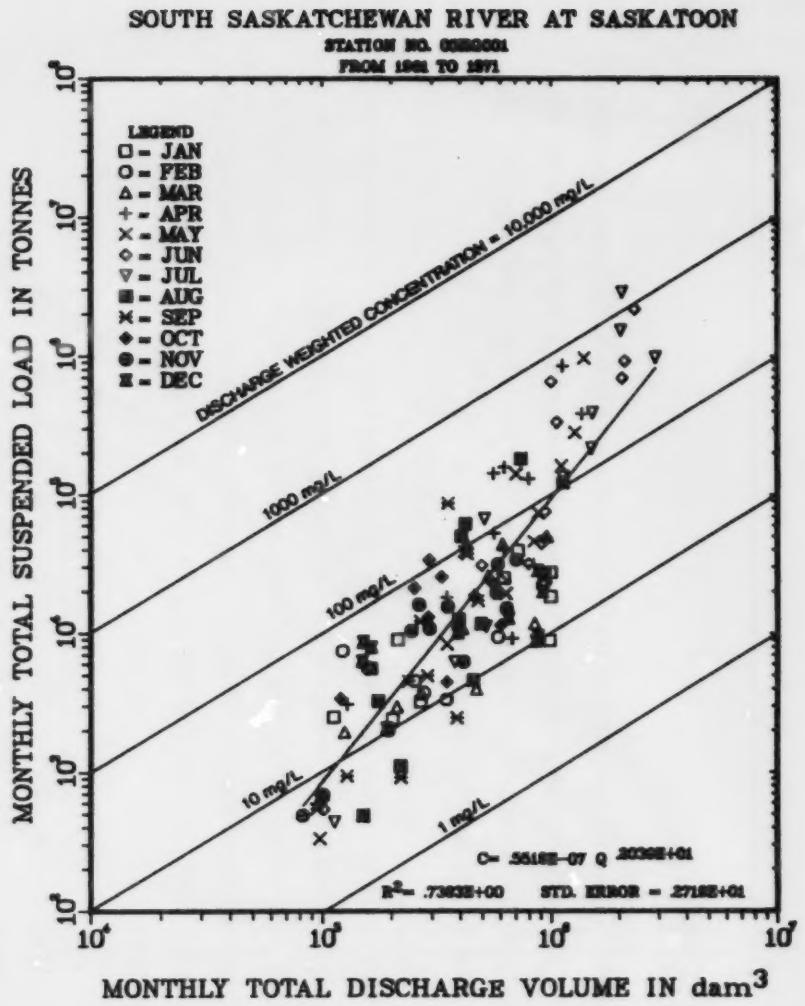


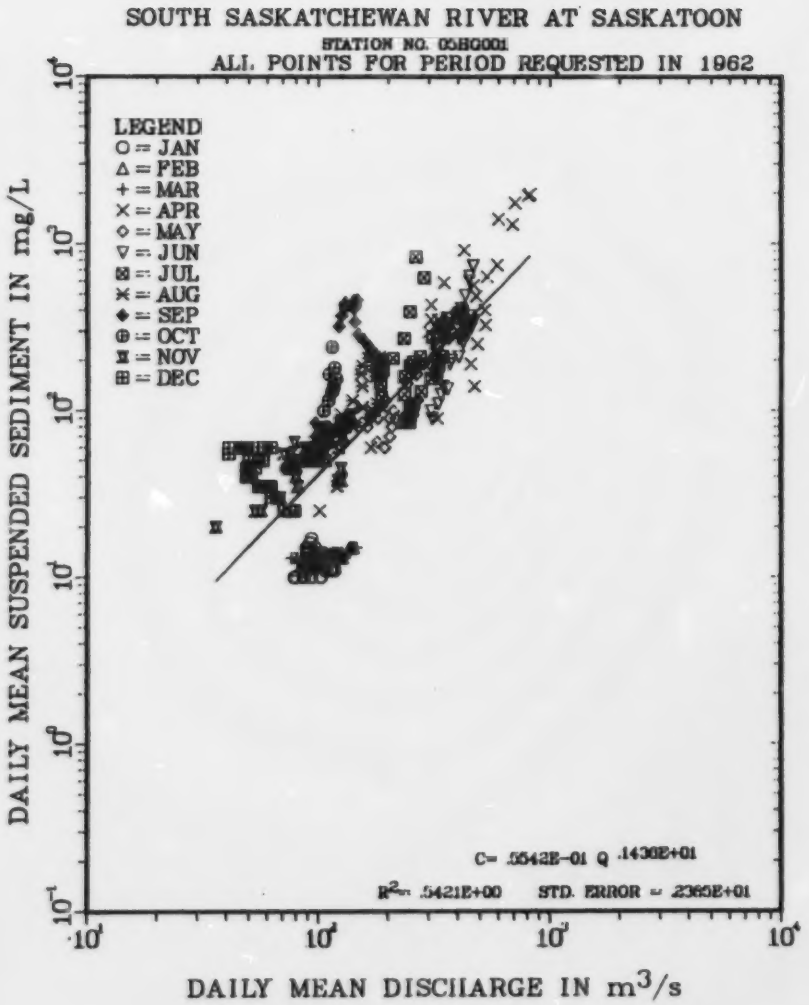
Figure 20 Rating Relationships for Monthly Mean Suspended Sediment Concentration and Monthly Loading

should be noted that each of the illustrations on Figures 20 depict essentially the same data, however, the fact that discharge is a component of load reduces the scatter in the load diagram. For any given discharge, the load varies by an order of magnitude.

Both of these trends are better illustrated using daily data. Data from 1962 and 1969 are shown in Figure 21. By tracing the temporal sequence in these data and cross-referencing with the annual hydrograph (Figure 14), the strong seasonal pattern of higher concentrations (and hence loadings) and greater variability during the rise to peak discharge period, is made very evident.

Without exception, the annual range of daily concentration is at least two log units (2 to 200 mg/L), and in years of high discharge, events can extend through three log units. Table 8 summarizes concentration extremes for the period 1961 - 1971 and 1975. The maximum concentration on record is 2 510 mg/L, (July 7, 1963).

Concentration and load duration curves are shown in Figure 22. These are daily mean data for the full year. These diagrams further illustrate that most of the suspended sediment is transported during infrequent events. For example, from Figure 22, daily mean concentrations greater than 100 mg/L occur less than 18% of the time.



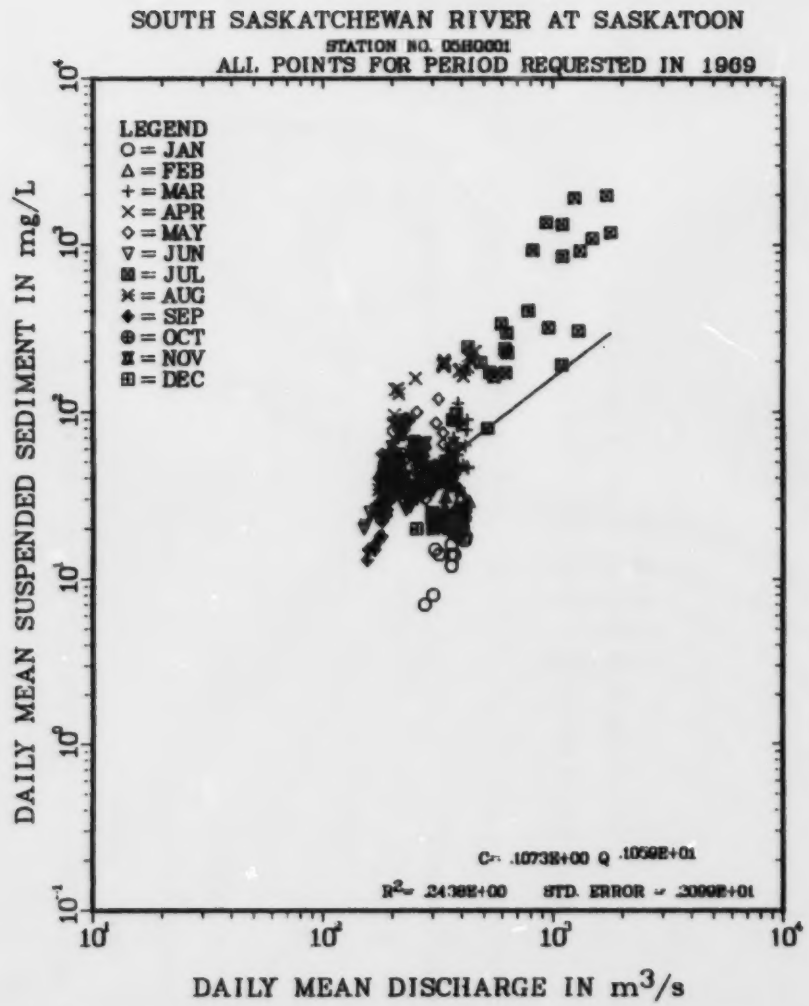


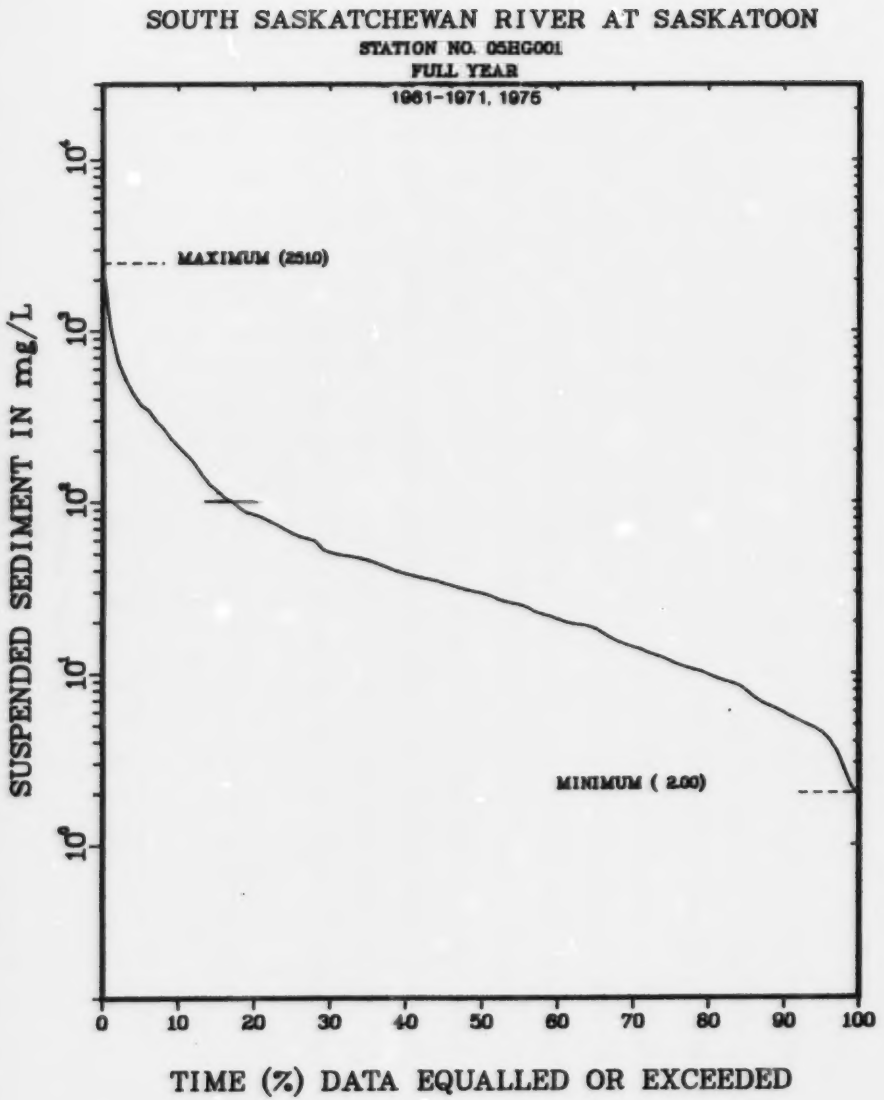
Figure 21 Mean Daily Concentration Data Versus Mean Daily Discharge Data for 1962 and 1969

TABLE 2
SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
HISTORICAL SEDIMENT CONCENTRATION DATA SUMMARY

Year	Period of Record	Type of Operation	Sampled Concentration (mg/L) Maximum		Minimum	
1961	June - December	M-S	390	June 24	5	December 12
1962	January - December	M-C	1 970	April 11	11	January 19
1963	January - December	M-C	2 510	July 7**	9	January 7
1964	January - December	M-C	1 610	June 18	5	September 11
1965	January - December	M-C	700	June 27	2	December 1**
1966	January - December	M-C	580	April 7	3	September 2
1967	January - December	M-C	235	July 5	3	May 24
1968	January - December	M-C	79	Nov. 8	2	May 24
1969	January - December	M-C	1 910	July 4	13	September 10
1970	January - December	M-C	108	June 25	4	September 6
1971	January - December	M-C	83	June 16	2	September 8
1975	June - June*	M-MS	2 110	June 24	257	June 30

M - Manual Sampling
C - Continuous Operation
S - Seasonal Operation
MS - Miscellaneous Operation

** - Extreme for Period of Record
* - Period of Record Incomplete



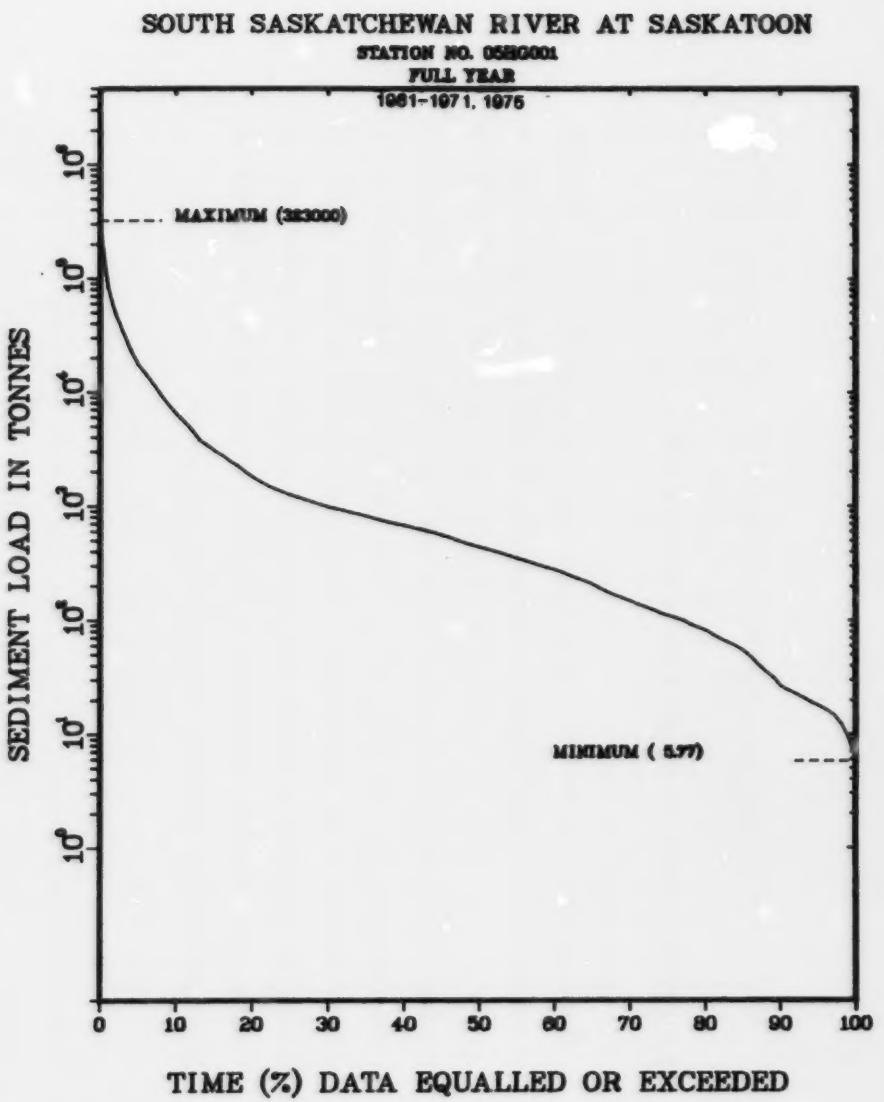


Figure 22 Duration Curves for Daily Mean Concentration and Daily Load

4.3 PARTICLE SIZE OF SUSPENDED SEDIMENT

All measured suspended sediment is less than 2 mm in diameter. Particle size data from 45 samples are shown in Figure 23 (the data are contained in Appendix D). As large amounts of sediment are required to determine a particle size gradation, an analysis is typically only done when sample concentrations are over 300 mg/L. However, samples were analyzed for concentrations as low as 50 mg/L. Thus, samples were primarily collected during the March-June period and mainly represent the rise-to-peak period. Only in 1963 are data available for September. In other years, data often are available for July, covering post peak flow conditions.

As illustrated in Figure 23, the suspended load is predominately sand (1 to 75% by weight, mean = 42.4%). The clay content varies from 3 to 64%, (mean = 18.2%), and the silt content varies from 19 to 68% (mean = 39.4%).

Wash load is usually defined as that part of the sediment load which is comprised of particles not found in significant quantities in the bed (Vanoni, 1975; Tywoniuk, 1972; Simons and Senturk, 1976). As indicated previously, (Section 4.1.2), the analysis of bed material samples indicates that on average silt and clay comprised approximately 11% of the bed material. Therefore, based on this definition, silt and clay can be considered to be the wash load component. Wash load has been found to be controlled by basin supply rather than hydraulics (Kellerhals et al., 1974; Simons and Senturk, 1976), therefore explaining the poor relationship with discharge, illustrated in Figure 24. There also appears to be a reduction in wash load (silt and clay) percentage at high flows, which may be due to two causes:

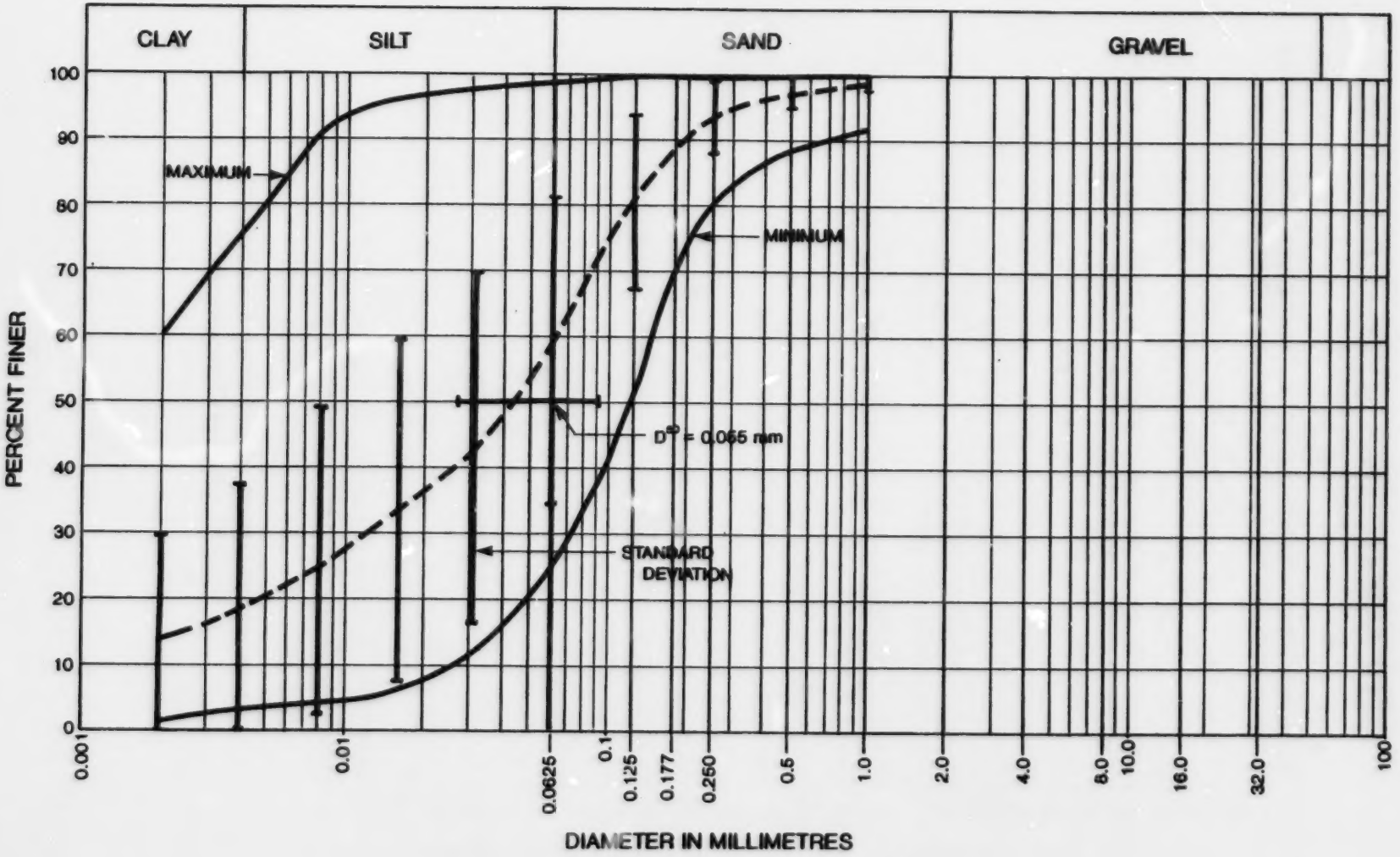


Figure 23 Summary of Suspended Sediment Particle Size Gradations

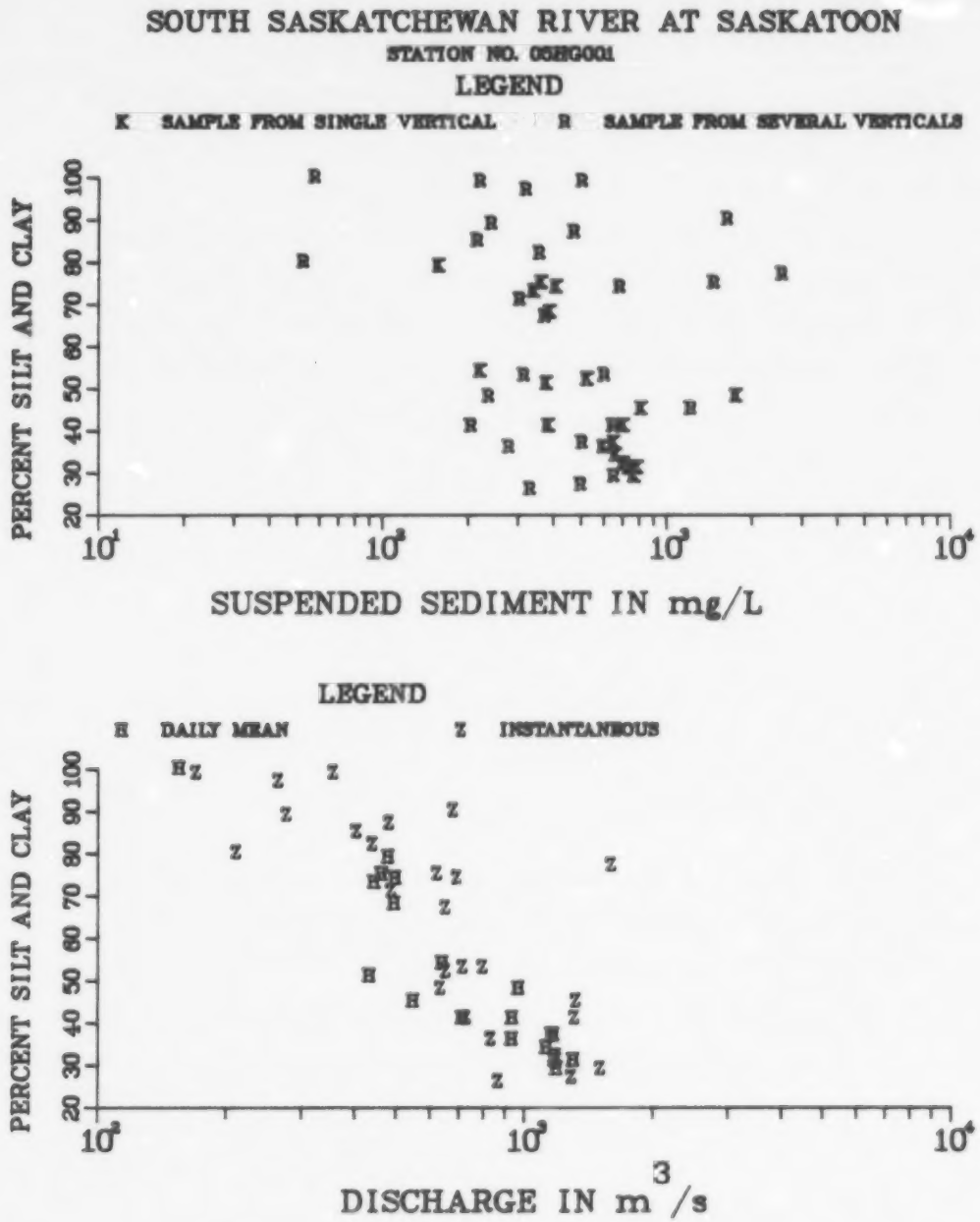


Figure 24 Variation of Silt-Clay Fraction With Discharge and Concentration

- expenditure of the stream's energy on bed material (sand and gravel) transport, thereby reducing the proportion of wash load (silt and clay),
- should the basin supply rate of sediment reach its full capacity, an increase in discharge would reduce the wash load component by dilution. This may be the case, as indicated by the upper portion of Figure 24, which shows a decrease in the silt and clay (wash load) percentage as concentration increases. Thus, there may be a limit to the supply of sediment (silt and clay) from the basin.

The D_{50} of the suspended load has a mean of 0.055 mm (Figure 25) and has a wide range (from about 0.0022 mm to 0.123 mm) due to the influence of wash load. The D_{50} appears to increase with discharge, indicative of the increasing stream power and hydraulic influences in general at higher discharges. As indicated in Figure 25, there is a poor relationship between grading and discharge, although grading may be expected to increase with discharge due to a decrease in wash load.

A visual comparison of the sand component of the total concentration of suspended sediment (for samples for which particle size data are available) is given in Figure 26. There is a strong indication of increasing sand concentration with increasing discharge. This is to be expected as there is a direct relationship between stream hydraulics (discharge) and bed material (sand) transport capacity. It should be noted that the data in Figure 26 are from various years, and thus there is much more scatter than in the annual rating plots of concentration versus discharge (Appendix E). The D_{50} and grading of the sand component is shown in Figure 27. The sand component is fine to medium sand (mean D_{50} = 0.128 mm), and narrowly graded. No trend in either parameter is apparent with increasing discharge.

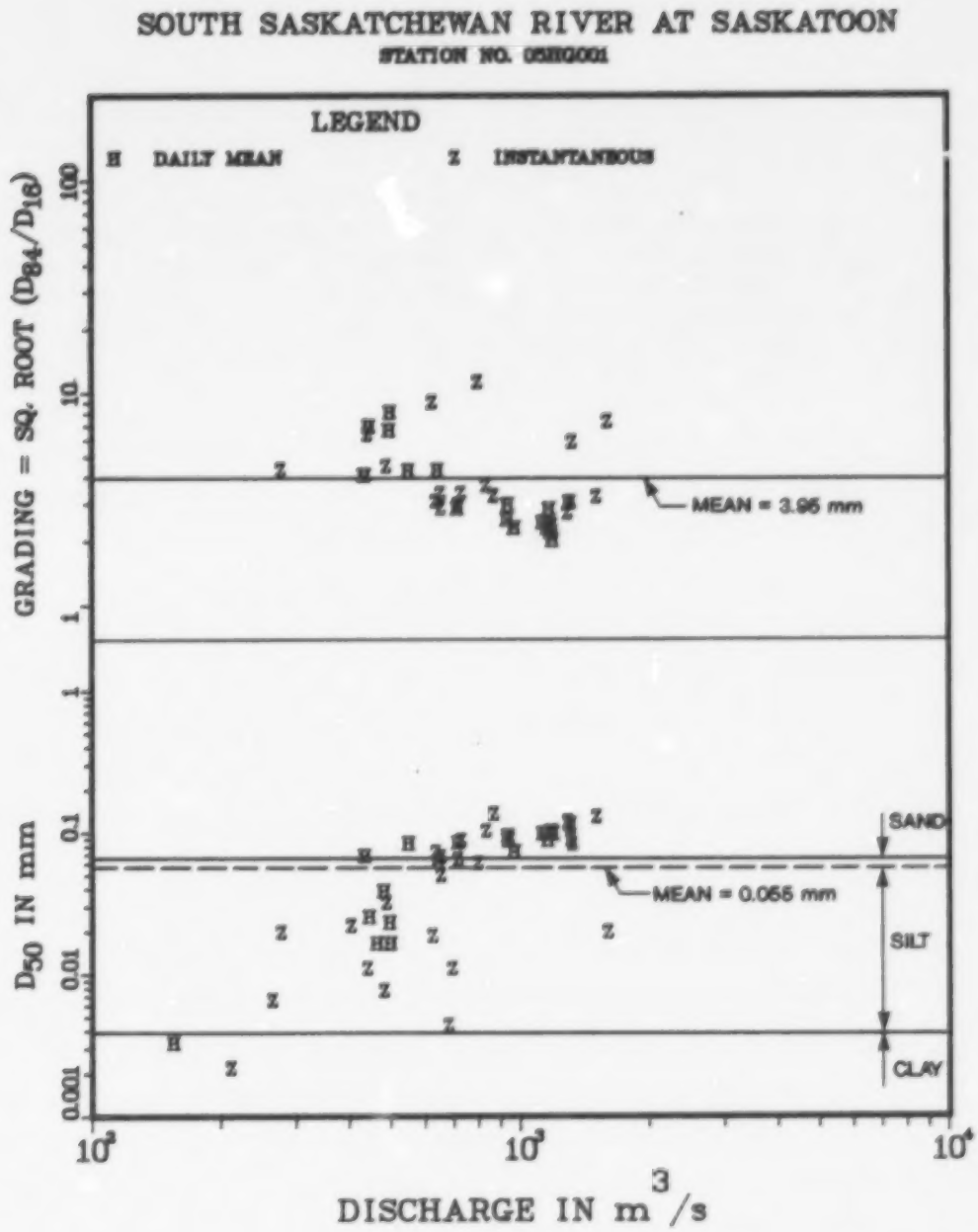


Figure 25 D_{50} and Grading of Suspended Sediment Versus Discharge

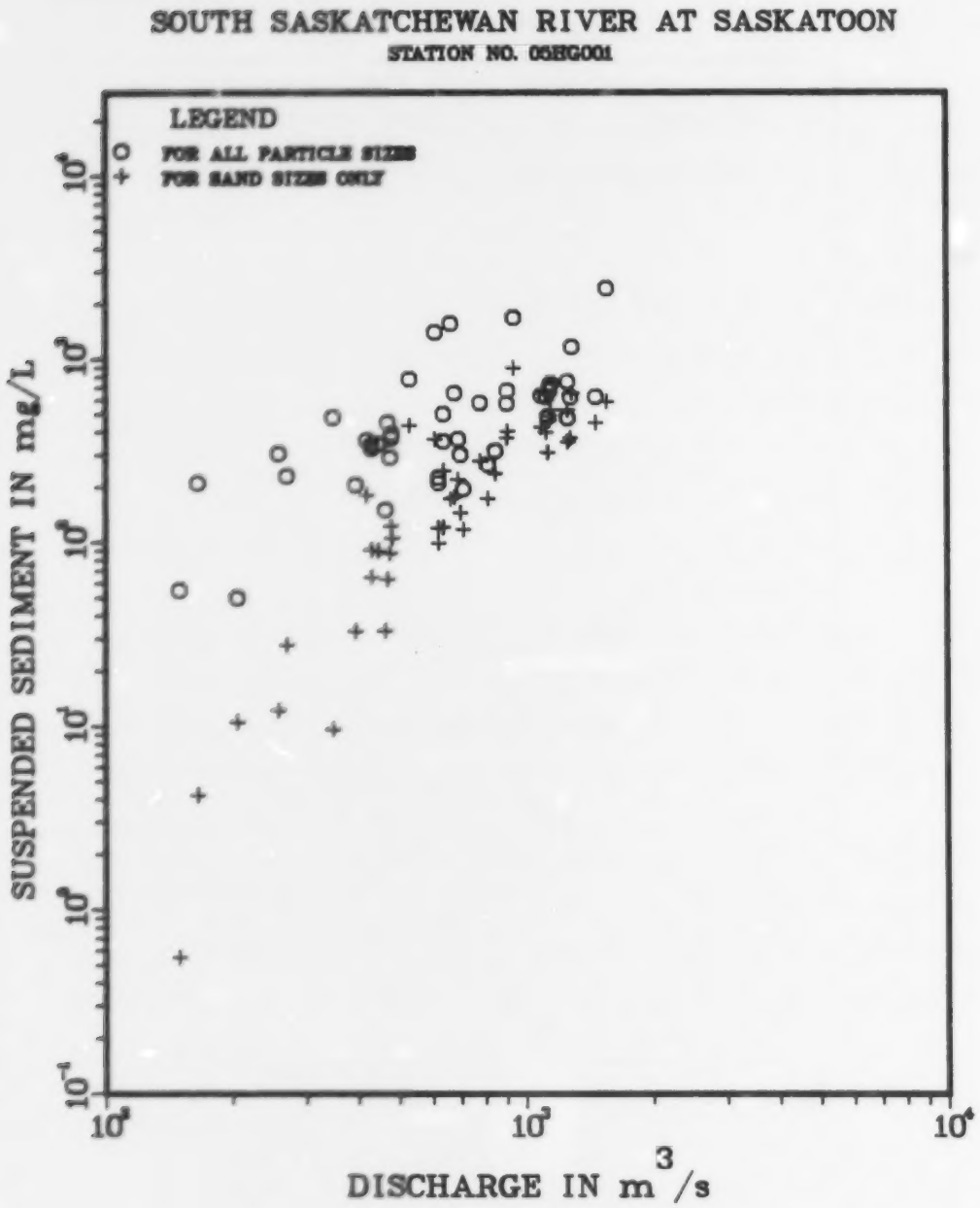


Figure 26 Variation of Suspended Sediment Concentration With Discharge. Sand Component Shown Separately

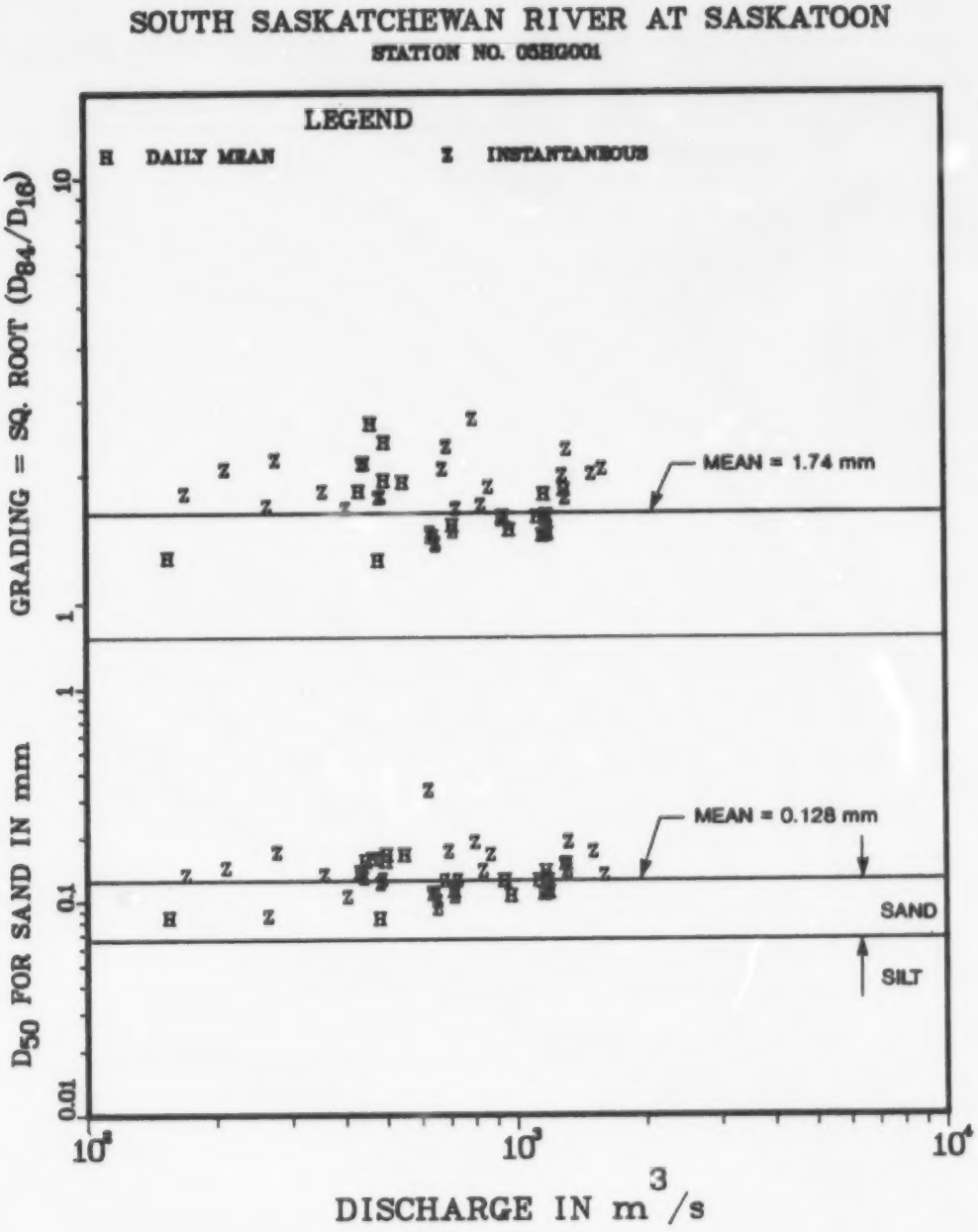


Figure 27 D_{50} and Grading of the Sand Component of Suspended Sediment Versus Discharge

4.4 SUSPENDED LOAD

For the period 1962 - 1971 (there is insufficient data for 1961) annual loadings show considerable variation. The range is from 91 900 tonnes (1968) to 4 060 000 tonnes (1963). These loading data are listed in complete form in Table 9.

The relationship between total annual load and discharge is shown in Figure 28. These data range across two full logarithmic scales (10^5 to 10^7 tonnes). A simple regression equation has been fitted to the logarithmically transformed data to demonstrate their consistency. The regression equation is given on Figure 28. The scatter in this plot may be due to the influence of Gardiner Dam, (Section 5.2)

The sequential pattern of loadings since 1962 is shown in Figure 29. The contributions of high load years of 1969 (particularly), 1963 and 1964 is dramatically shown. Nonetheless, the possible impact of Gardiner Dam in reducing sediment loads is evident in the later years of the plot in Figure 29.

Between June 1961 and December 1971, approximately 16.6×10^6 tonnes of suspended sediment were transported past Station 05HG001, with over half of this material being silt. An average 1.6×10^6 tonnes of suspended sediment were transported each year. The influence of Gardiner Dam is modifying the mean annual sediment load is discussed in Section 5.2.

TABLE 9

SUMMARY OF MONTHLY AND ANNUAL SUSPENDED SEDIMENT LOADS (TONNES)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961	-	-	-	-	-	94980	67229	50094	12215	13100	15352	2089	-
1962	3222	3748	3687	845762	141030	334390	178520	61634	86598	21177	16089	6326	1 702 183
1963	2505	7485	44359	158458	38684	654306	2885800	181770	37360	25477	10427	8707	4 055 338
1964	9028	2014	1953	142522	966645	2173180	391740	12613	4540	33685	10817	7951	3 756 688
1965	5598	695	2967	52714	280550	921470	979500	122524	33167	48922	6265	10073	2 464 445
1966	2422	4558	44163	384423	161256	696900	218110	3252	546	644	492	654	1 517 460
1967	39511	9409	3977	39696	73701	75459	134811	4611	4963	3412	5702	8806	404 058
1968	8875	3345	10833	3091	333	543	441	490	945	18669	31527	12825	91 917
1969	18383	23963	49990	130180	45988	31754	1525942	24979	17137	23813	33951	19950	1 946 030
1970	27464	33430	25794	18074	8356	30862	11215	11746	2469	11478	19555	28300	228 743
1971	26155	22097	11816	9204	19270	44406	6246	1115	919	4478	15042	9570	170 318
Mean	14316	11074	19954	178412	173585	496327	633233	42473	18863	19176	14987	11316	1 633 718
Percent Annual	0.88	9.68	1.22	10.92	10.63	30.38	38.76	2.60	1.15	1.17	0.92	0.69	
Std. Dev.	12918	11298	19436	260753	291963	678531	934355	62152	27455	15011	10883	7695	1 459 901
C.V.	0.902	1.02	.974	1.46	1.68	1.37	1.48	1.46	1.46	.783	.726	.680	0.894
Max.	213700	33430	49990	845762	966645	2173180	2885800	181770	86598	48922	33951	28300	4 055 338
Min.	2422	695	1953	3091	333	543	441	490	546	644	492	654	91 917

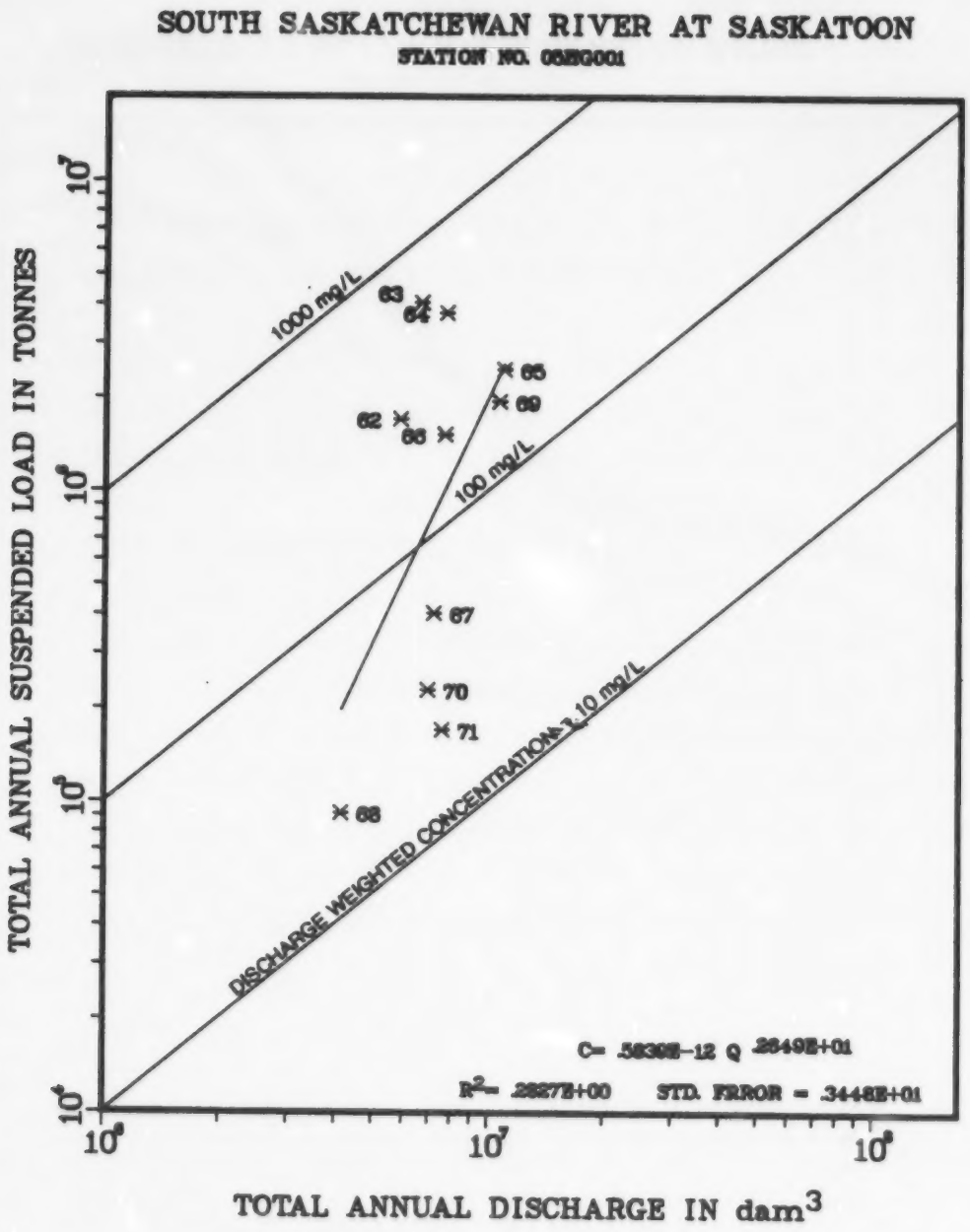


Figure 28 Relation Between Total Annual Suspended Sediment Load (tonnes) Versus Total Annual Discharge (dam^3) for the Period 1962-1971

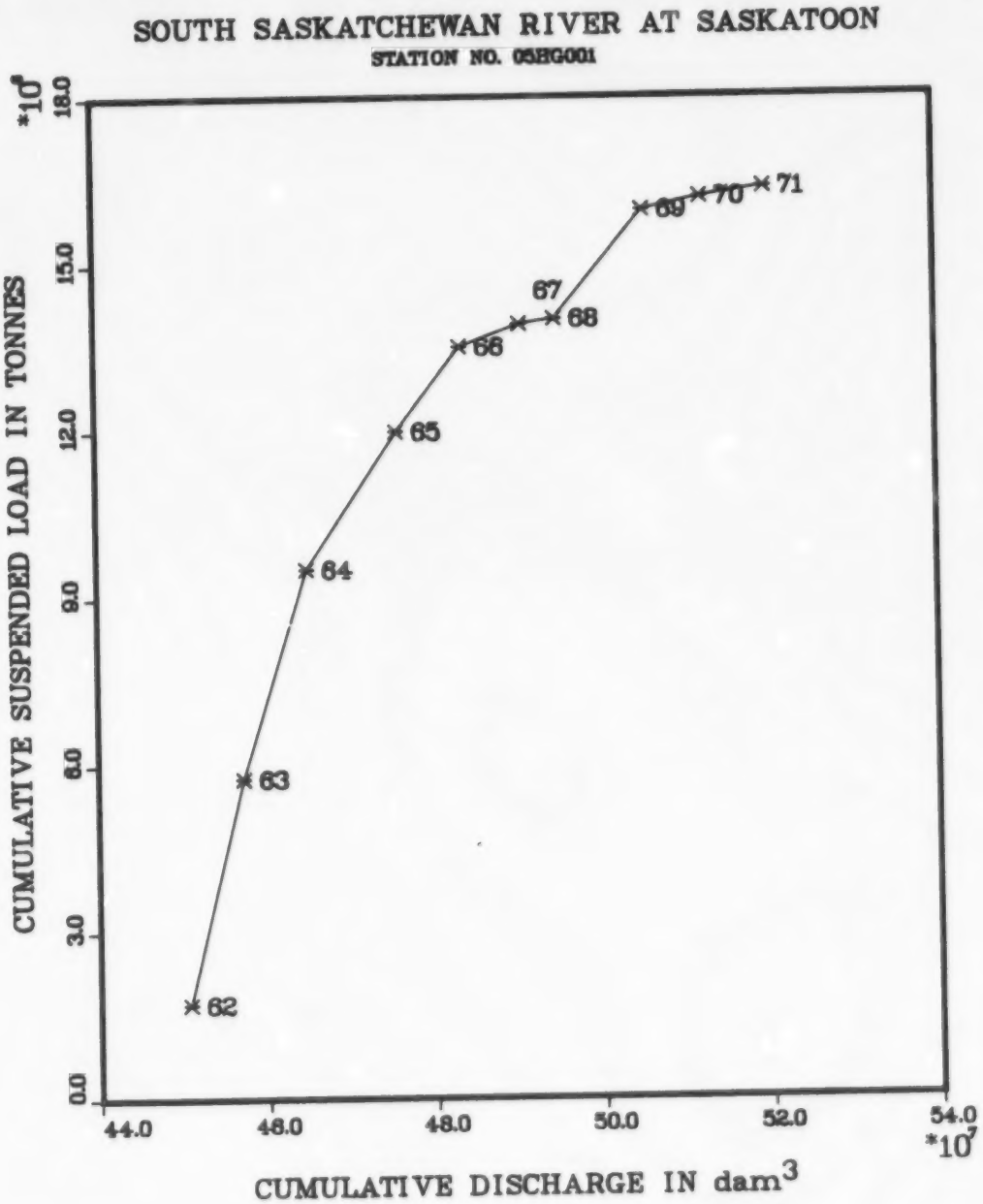


Figure 29 Double Mass Plot of Annual Suspended Load Versus Annual Discharge for the Period 1962-1971

4.5 CONCENTRATIONS

Annual mean concentrations of suspended sediment vary greatly from 16 mg/L (1968) to 220 mg/L (1963) (Table 10). These data are plotted against annual mean discharge in Figure 30. A regression line is fitted to these data only to provide a means of comparison.

For the 10 years of record, which covers both pre-dam and post-dam periods, the mean annual mean concentration is 88.6 mg/L. The influence of Gardiner Dam on sediment concentrations is discussed in Chapter 5.

4.6 POINT INTEGRATING SUSPENDED SEDIMENT DATA

Point integrating suspended sediment data and plots are available for six dates in the mid-1960s, (see Appendix F). Discharges range between approximately 527 m^3/s and 1280 m^3/s, while mean concentrations vary from 493 mg/L to 1239 mg/L. The plots indicate a great variability in wash load concentrations with depth. Concentrations are usually highest near the bed, and decrease towards the surface. Sand (bed material) concentrations are also highest near the bed, and decrease sharply towards the surface.

4.7 YIELD

Sediment yields (tonnes/km^2) are listed in Table 10 and plotted in Figure 31. Sediment yields range from 0.65 tonnes/km^2 (1968) to 28.8 tonnes/km^2 (1963), with a mean of 11.6 tonnes/km^2 (see Table 10). These data are loosely correlated to total annual discharge as indicated by the results of a

TABLE 10

SUMMARY OF ANNUAL DATA FOR FLOWS, LOADS AND YIELDS

SOUTH SASKATCHEWAN RIVER AT SASKATOON

TABLE OF ANNUAL DATA

Year	Annual Flow in dam^3	Annual Load in tonnes	Annual Flow in dam^3/km^2	Annual Load in $tonnes/km^2$	Annual Mean Flow in m^3/s	Annual Mean Conc. in mg/L	Cumulative Flow in dam^3	Cumulative Load in tonnes
1961	5 640 000		40.0		179		444 790 000	
1962	5 860 000	1 702 182.9	41.6	12.1	186	156	450 650 000	1 702 183
1963	6 630 000	4 055 338.6	47.0	28.8	210	220	457 280 000	5 757 522
1964	7 710 000	3 756 688.0	54.7	26.6	244	156	464 990 000	9 514 210
1965	10 900 000	2 464 446.05	77.3	17.5	346	97	475 890 000	11 978 656
1966	7 650 000	1 517 460.31	54.3	10.8	242	68	483 540 000	13 496 116
1967	7 190 000	404 057.7	51.0	2.87	228	37	490 730 000	13 900 174
1968	4 140 000	91 916.59	29.4	0.65	131	16	494 870 000	13 992 090
1969	10 600 000	1 946 030	75.2	13.8	336	86	505 470 000	15 938 120
1970	6 940 000	228 742.4	49.2	1.62	220	31	512 410 000	16 166 863
1971	7 570 000	170 317.2	53.7	1.21	240	19	519 980 000	16 337 180

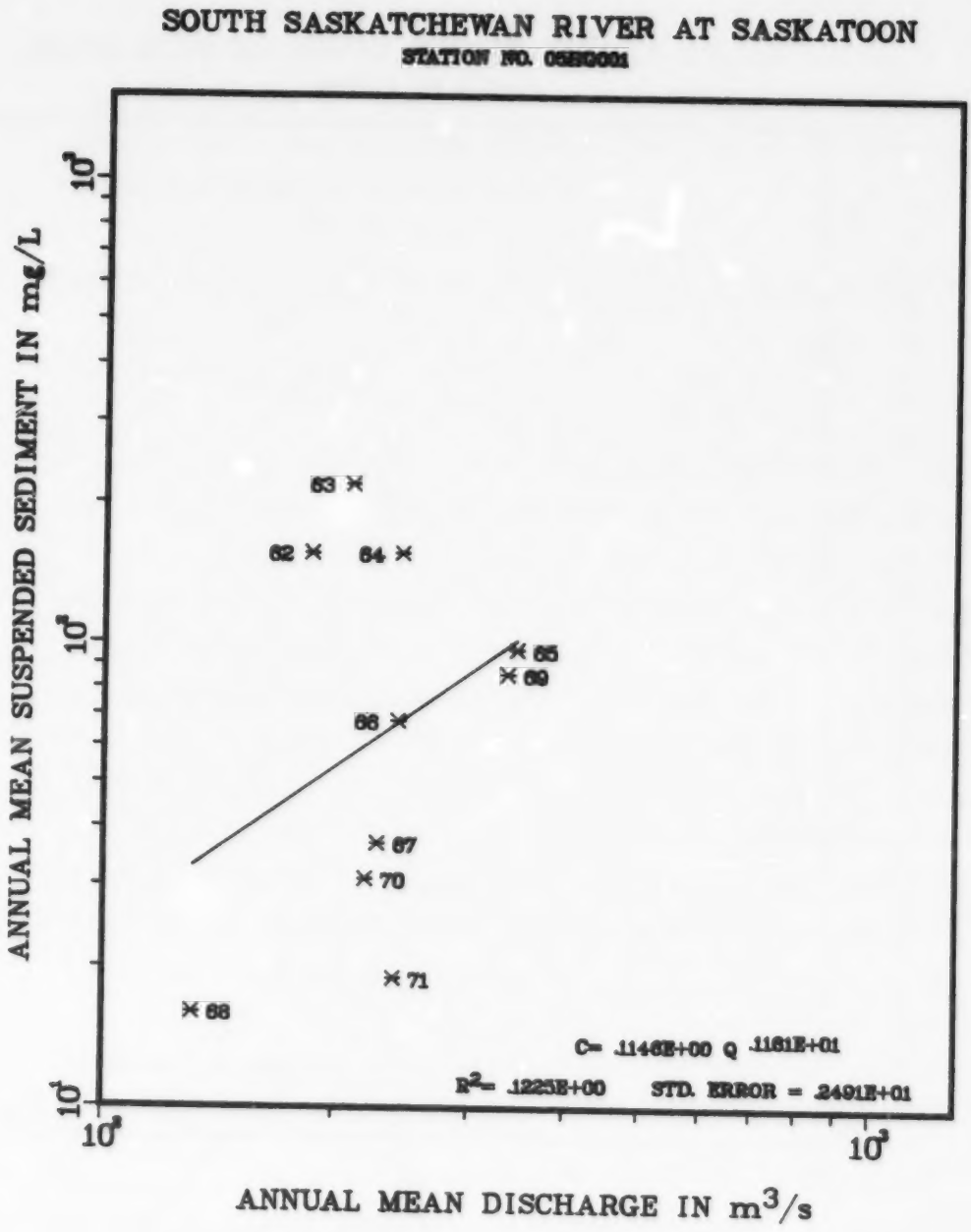


Figure 30 Relation Between Annual Mean Suspended Sediment Concentration and Annual Mean Discharge

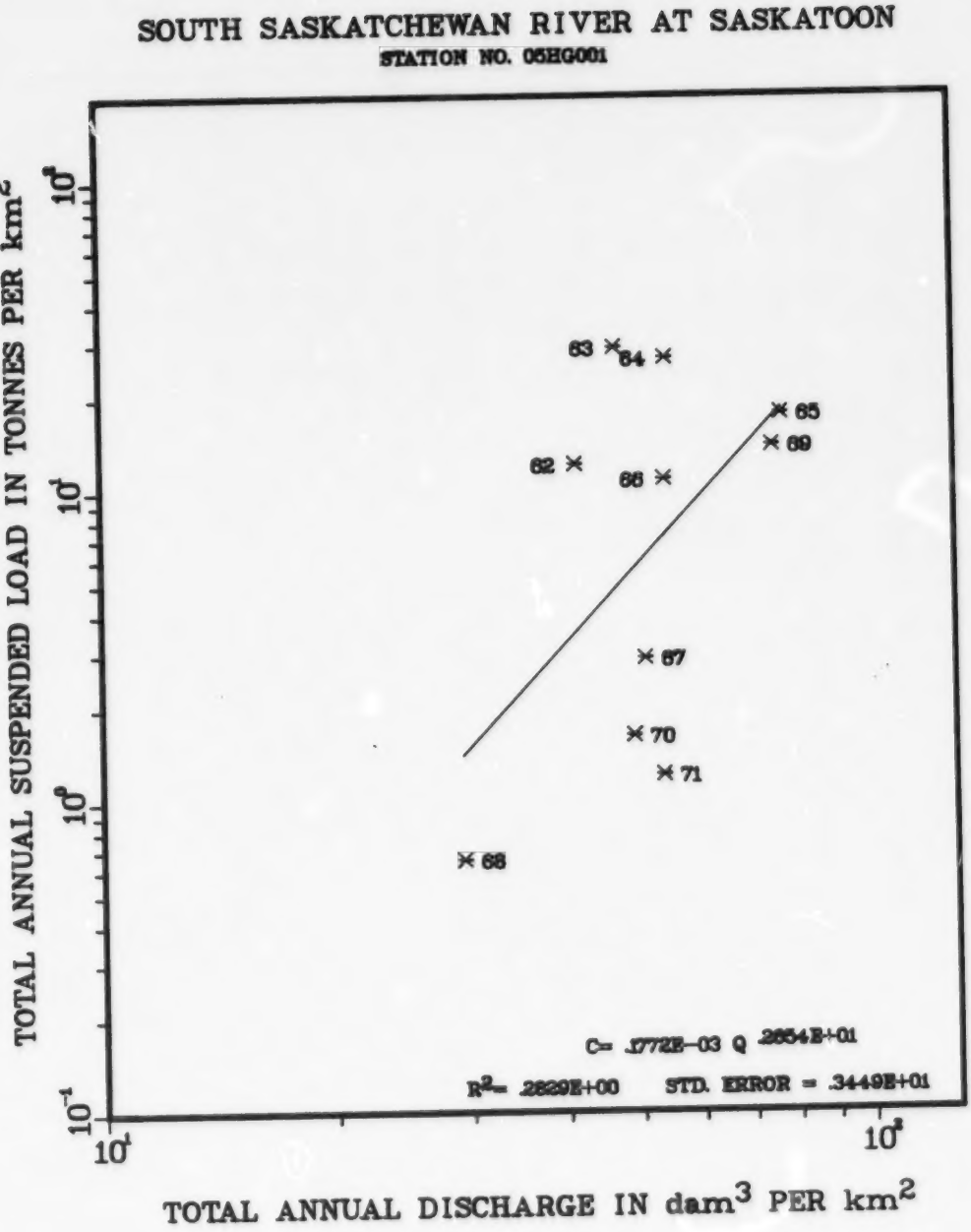


Figure 31 Sediment Yield Plot for 1962-1971

regression analysis and the results are included on Figure 31. A better fit to the relationship may be possible if sediment contributing area was used to derive yield instead of the gross basin area.

5.0 IMPACTS OF GARDINER DAM ON SEDIMENT TRANSPORT

5.1 GENERAL

The Gardiner Dam was constructed on the South Saskatchewan River, about 75 km upstream of Saskatoon, between 1959 and 1968 (actual river closure took place on February 14, 1964). At Full Supply Level (FSL) of 556.87 m, the reservoir (Lake Diefenbaker) has a total storage volume of 9 363 000 dam^3 or 1.15 times the mean annual flow of the river. On the basis of Brune's (1953) curves, trap efficiency for the reservoir may be estimated at 95 - 100%. Thus, the majority of the sediment entering Lake Diefenbaker is stored in the reservoir. This sediment storage in the reservoir results in the release of "clean" water from the dam, which promotes degradation of the downstream channel. Degradation below Gardiner Dam has been the subject of numerous investigations, including Galay *et al.* (1982, 1985), Rasid (1979), and Yuzyk (1987).

The following discussion addresses the effects of Gardiner Dam on sediment transport as indicated by the sediment data gathered at Saskatoon between 1961 and 1975.

5.2 SEDIMENT LOADS

Annual load data is available for the South Saskatchewan River at Saskatoon from 1962 to 1971. This period covers pre- and post-dam conditions.

Figure 32 illustrates the relationship between total annual discharge and total annual suspended load. There appears to be a variation between the pre-dam period (1963 and earlier) and the post-dam period (1964 and later). Suspended sediment loads following closure are less than for an equivalent discharge prior to closure. This variation does not appear to be as distinct as that illustrated in either Galay *et al.* (1982) or Galay *et al.* (1985) by a graph prepared by the W.S.C. (which for some unknown reason omitted data for 1969), or in Figure 18. It is thought that additional pre-dam sediment data covering a wider range of flows would have been useful in defining changes resulting from dam construction.

Changes in sediment load downstream of the dam as measured at Saskatoon may also be related to loads entering the reservoir as measured at Lemsford. Figure 33 illustrates the relationship between annual sediment loads at these sites. Three distinct zones are evident:

(i) Pre-reservoir data for 1962 and 1963 indicate that the loads are nearly equal for these sites. This is to be expected for the following reasons:

- the absence of major tributary inflows between the two sites,
- high percentage (58%) of the suspended load comprised of wash load (silt and clay),
- lack of obvious major areas of deposition

(ii) Post-reservoir data for 1967 - 1971 which indicate low sediment loads at Saskatoon relative to loads at Lemsford.

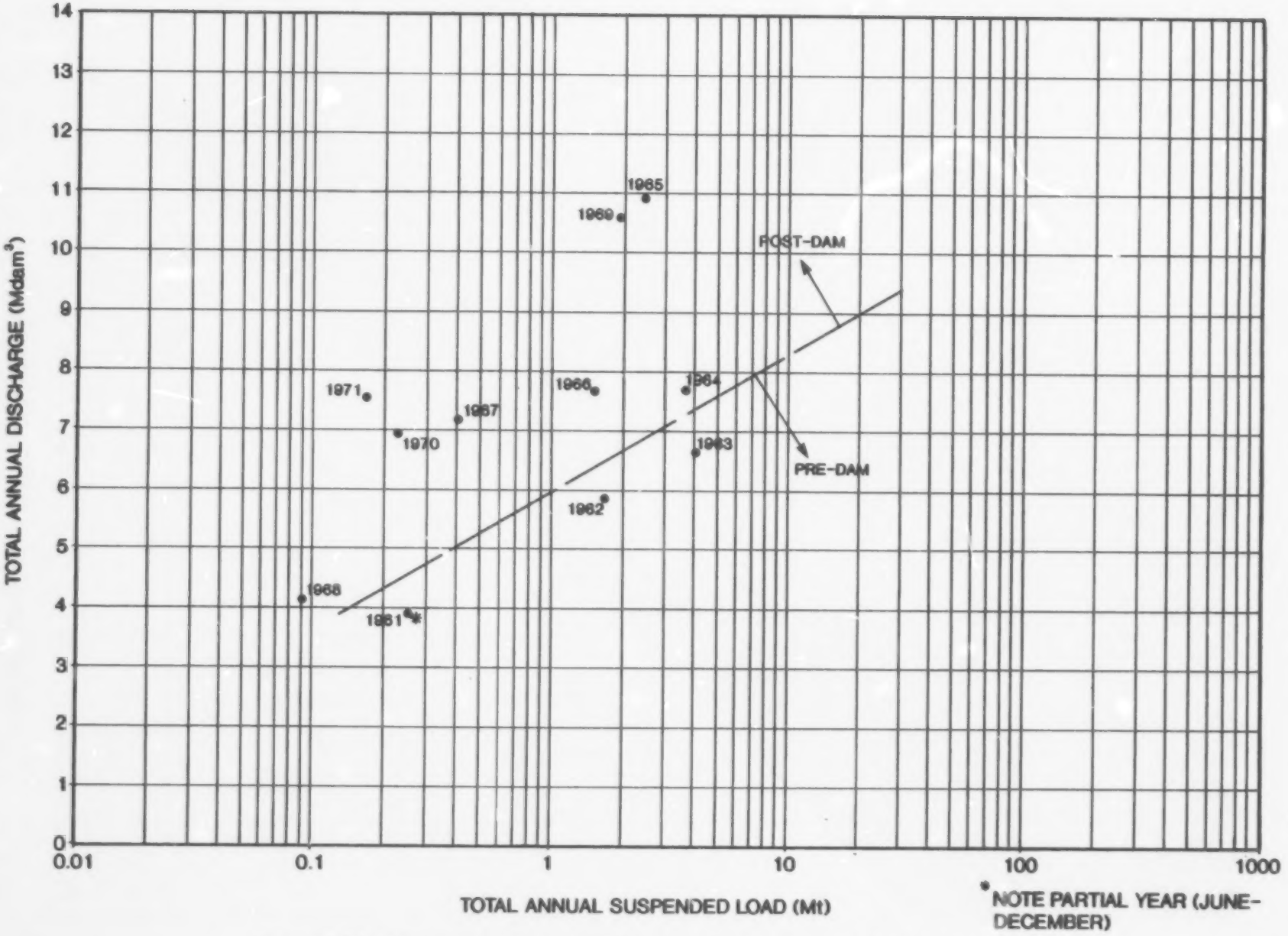


Figure 32 Change in Measured Suspended Sediment Load After Dam Closure

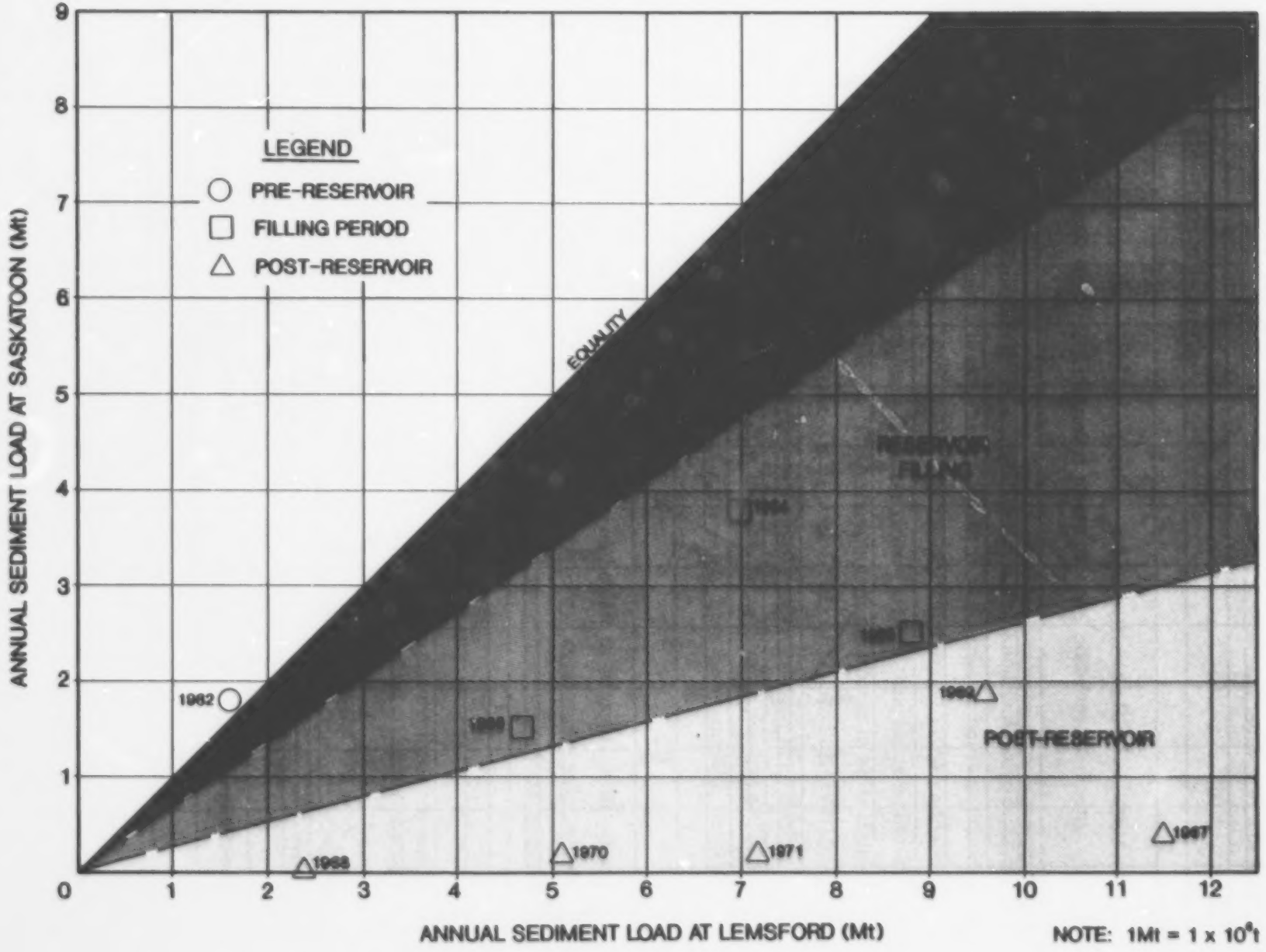


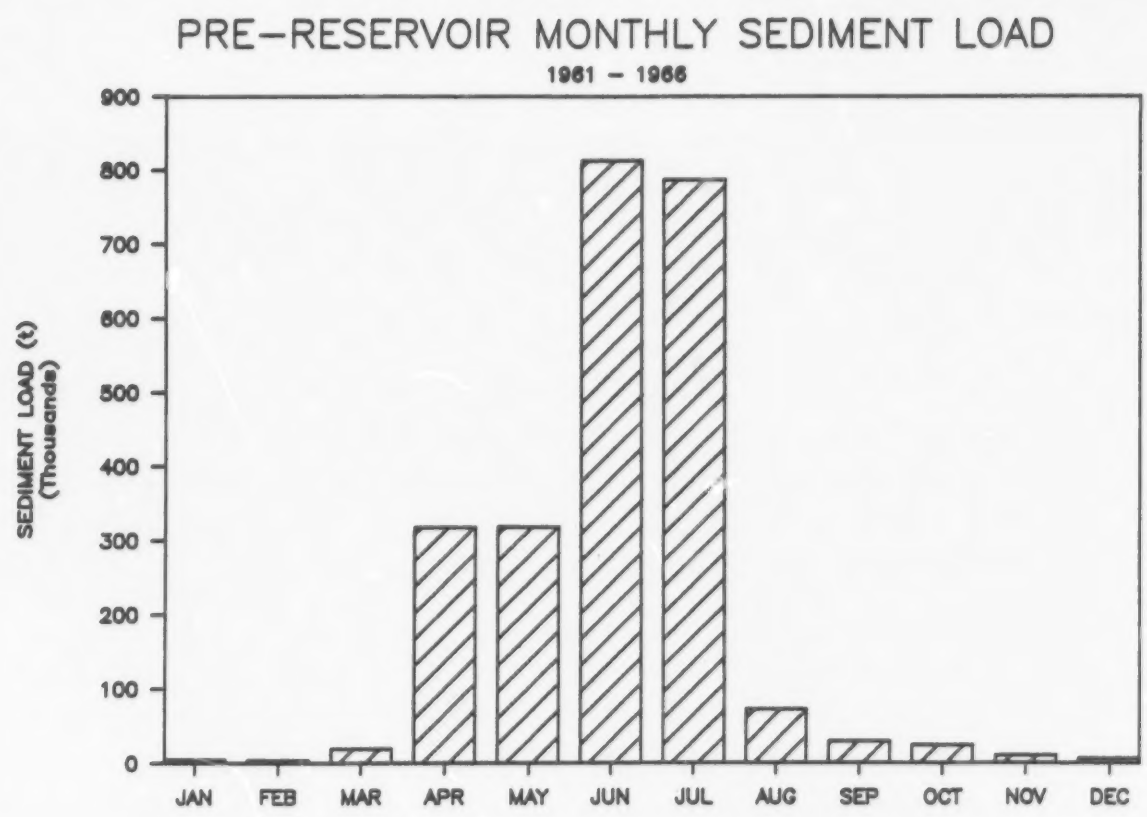
Figure 33 Annual Sediment Loads at Lemsford and Saskatoon

(iii) An intermediate zone representing the reservoir filling period from 1964 to 1966.

Figure 33 also indicates that significant sediment loads at Saskatoon may still occur. Given that the maximum historical annual load measured at Lemsford is in the order of 11.5 x 10^6t it may be reasonable to expect, on the basis of Figure 33, a total annual load as high as 3 x 10^6 at Saskatoon. However, this is still less than the 4 x 10^6 load measured prior to river closure.

The slope of a line from the origin to any of the points in Figure 33 is inversely proportional to the reduction in load at Saskatoon, and as well may indicate the trap efficiency of Lake Dienfenbaker. In 1962 and 1963, before river closure, the loads are nearly equal. During the filling period, trap efficiency increases until in the post dam period at least 88% of the sediment passing Lemsford is deposited in the reservoir before it reaches Saskatoon. Since the South Saskatchewan River picks up a certain amount of sediment in the 113 km reach between the Gardiner Dam and Saskatoon, it is difficult to estimate the actual suspended load that has passed through the outlet works of the dam, (Rasid, 1979).

The effects of Gardiner Dam on the seasonal variation in sediment loads at Saskatoon is dramatic. Figure 34 clearly illustrates the decrease in mean monthly flows for the April-October period under post-reservoir (1967 -1971) conditions. This is primarily due to significant flow regulation. This regulation which is clearly illustrated in Figure 4 and in Figure 35, is based on the storage of summer peak flows for release during the winter months.



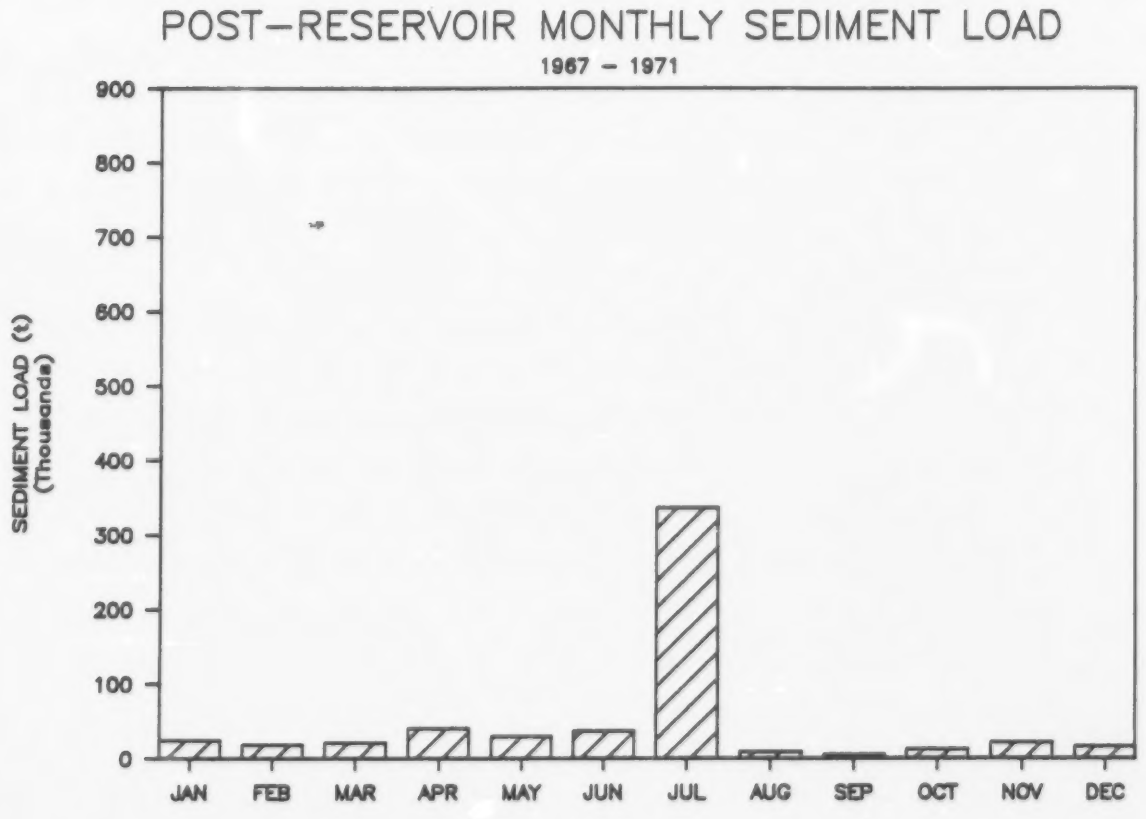


Figure 34 Pre- and Post-Reservoir Sediment Regimes

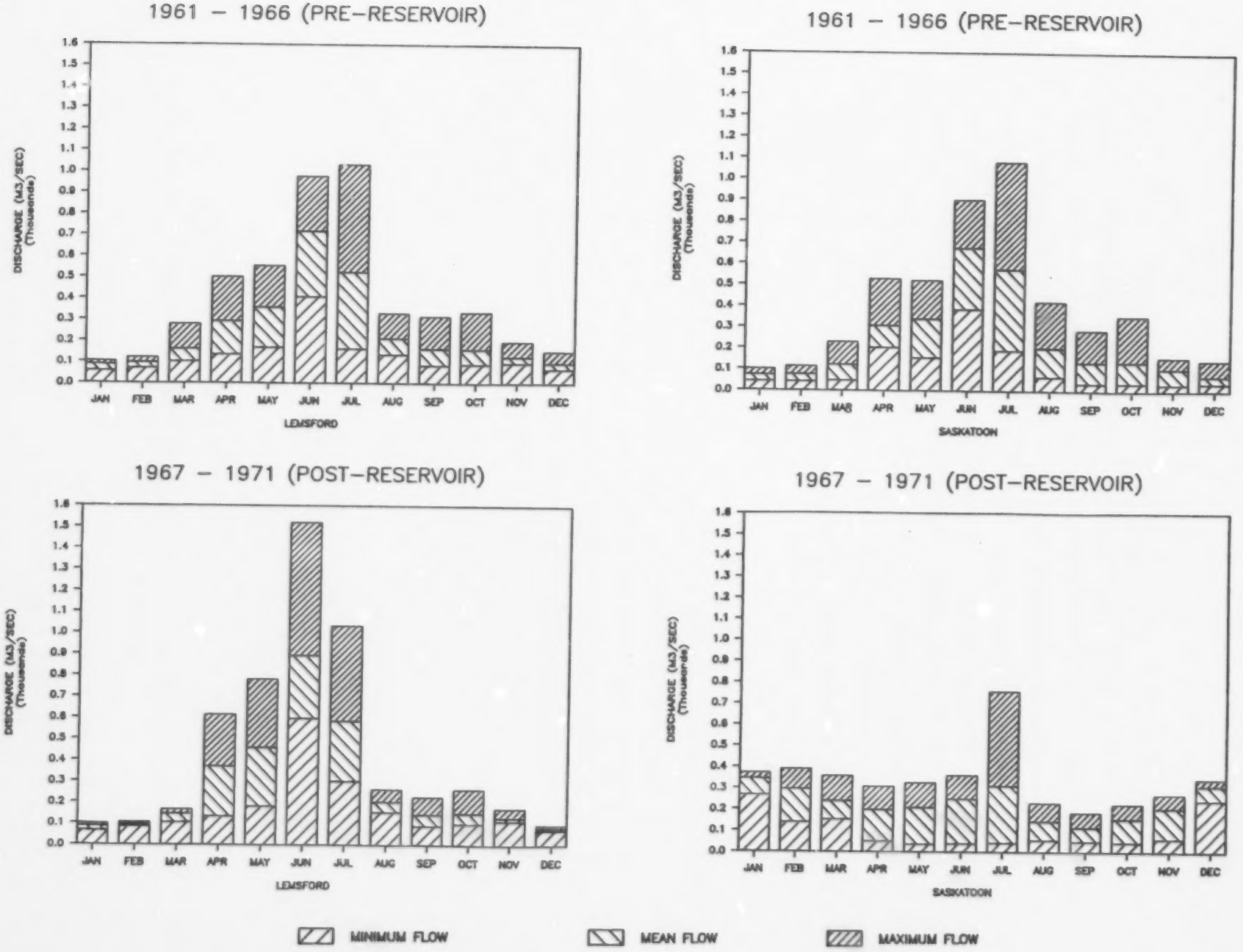

1961 – 1966 (PRE–RESERVOIR)
DISCHARGE (M3/SEC) (Thousands)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
LEMSFORD
1961 – 1966 (PRE–RESERVOIR)
DISCHARGE (M3/SEC) (Thousands)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
SASKATOON
1967 – 1971 (POST–RESERVOIR)
DISCHARGE (M3/SEC) (Thousands)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
LEMSFORD
1967 – 1971 (POST–RESERVOIR)
DISCHARGE (M3/SEC) (Thousands)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
SASKATOON
MINIMUM FLOW
MEAN FLOW
MAXIMUM FLOW

Figure 35 Pre- and Post-Reservoir Mean Monthly Discharges on the South Saskatchewan River

It follows that if the rating curve relationship for monthly mean discharge versus monthly mean suspended sediment concentration remains constant, then decreased summer flows, when the majority of the sediment is transported, will result in decreased concentrations and, hence, loads. Figure 36, which illustrates this relationship, indicates that pre-impoundment concentrations are generally higher for the same discharge than those under post-impoundment conditions. (The statistical significance of this observation was not tested). However, even so, there is every indication that post-impoundment monthly sediment levels (loads and concentrations) are less than pre-impoundment levels.

Maximum daily loads at Saskatoon during the period of record have been summarized in Table 6. The data for 1963 (323 000 t on July 8) representing pre-reservoir conditions is comparable to that for 1969 (293 000 t on July 5) representing post-reservoir conditions. (Discharge and sediment load calculations for these extreme events have been checked and verified for accuracy). The dam, however, does provide a reasonable degree of flood control, as indicated in Table 11.

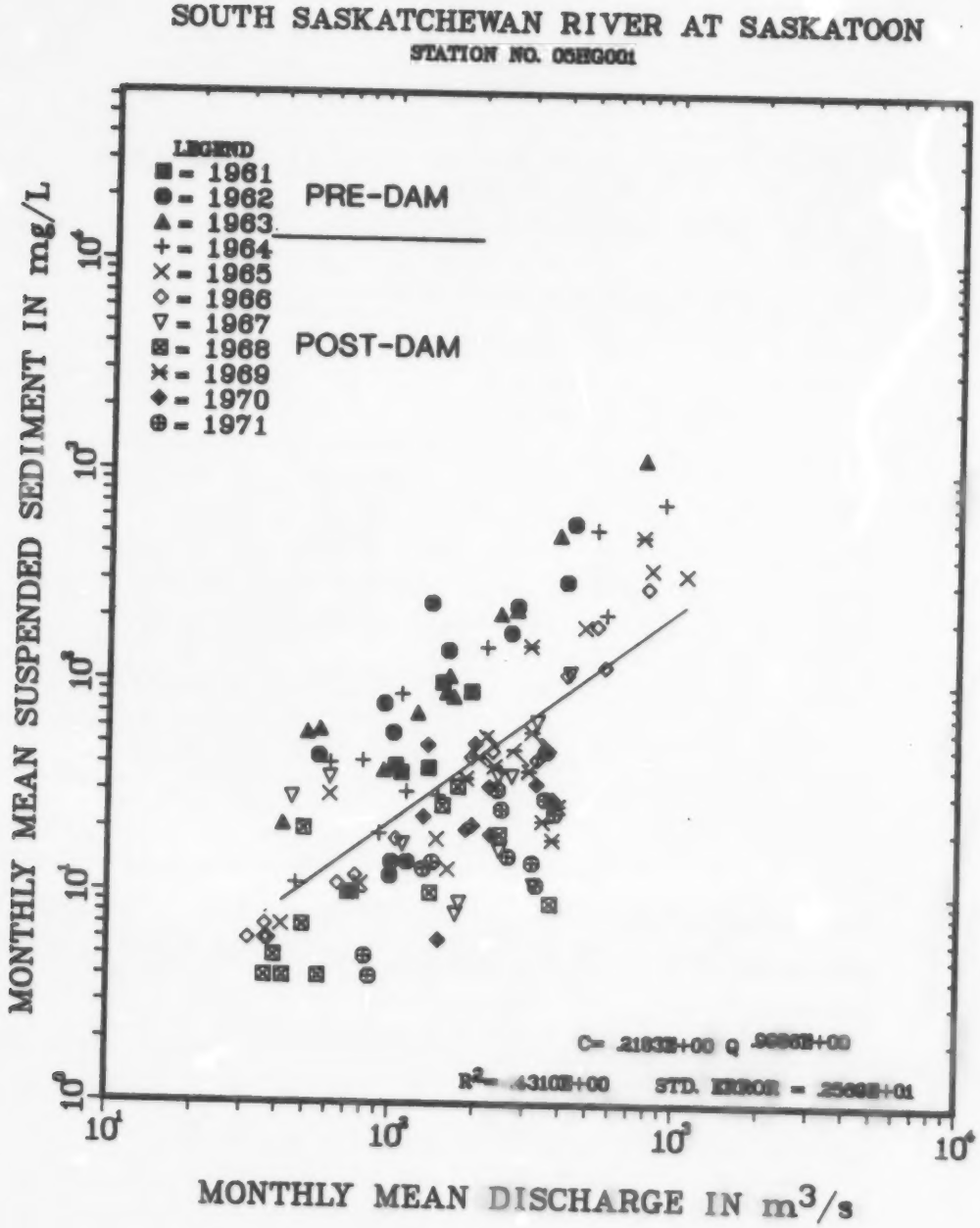


Figure 36 Monthly Mean Discharge and Sediment Concentration Relationship

TABLE 11

MAXIMUM DAILY FLOW REDUCTIONS AT SASKATOON
DUE TO GARDINER DAM
(from Saskatchewan Environment, 1980)

Return Period (years)	Lake Diefenbaker Discharge (m^3/s)		South Saskatchewan River Discharge at Saskatoon (m^3/s)
	Inflow	Outflow	
10	3200	2600	2120
50	5250	4950	4500
100	6250	5200	5080
500	8250	6450	6350

Thus, peak flows at Saskatoon under regulation are less than prior to the operation of Gardiner Dam. This, combined with a stable rating curve for peak events (Figure 37), indicates that peak sediment loads may be lower under regulation.

From the above analysis, it is evident that under regulation, suspended sediment concentrations and load are less at Saskatoon.

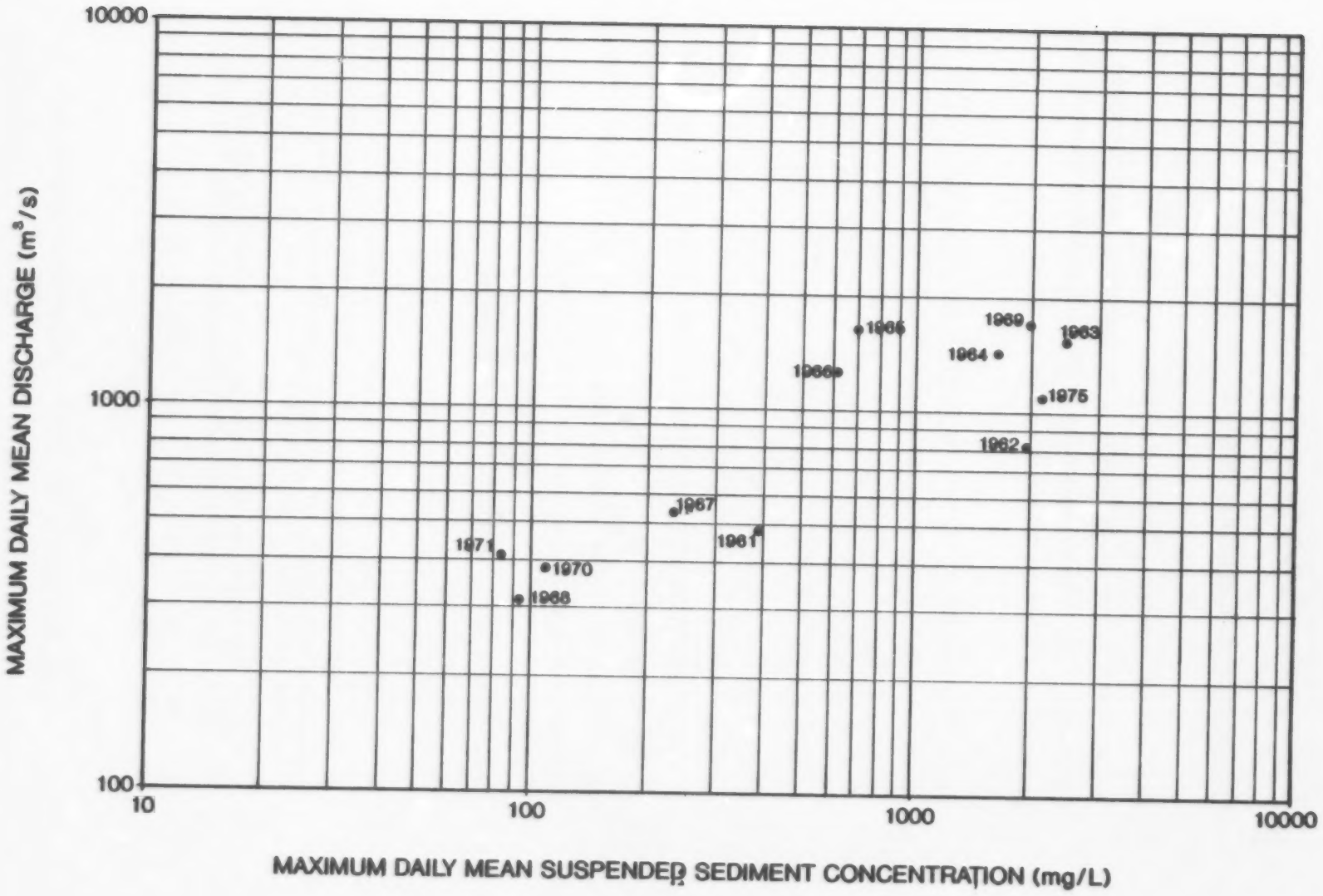


Figure 37 Rating Curve of Annual Peak Load Events

5.3 SEDIMENT CHARACTERISTICS

The general characteristics of the suspended sediment in the South Saskatchewan River at Saskatoon have previously been discussed in Section 4.3. The temporal variability of the sediment sizes resulting from the creation of Gardiner Dam will now be examined.

Figure 38 shows the changes in the sand, silt and clay components of the suspended sediment during the period of record. (In this figure, the average composition for all samples in each year has been indicated. No sediment size data is available for samples collected in 1967 - 1968, and 1970 - 1971). From Figure 38, it is evident that there has been a significant decrease in clay content and corresponding increase in sand content. Silt content has decreased slightly. This has been further illustrated by Ashmore's (1986) ternary diagram (Figure 39) which gives comparable results. The significance of this change may depend on the number of pre-regulation samples (15) compared to the number of post-regulation samples (30). The statistical significance of these changes has not been examined.

These changes may be explained by two processes resulting from the creation of Lake Diefenbaker:

(i) A significant proportion of the wash load component (silt and clay) of the suspended sediment load originating from the basin upstream of Lake Diefenbaker (see points for the Red Deer River and South Saskatchewan River in Figure 39) is deposited in the reservoir. As noted above, the trap efficiency for Lake Diefenbaker is high. Also, since the bed material at Saskatoon is comprised of only a small amount of these materials (11% as discussed in Section 4.1.2), virtually

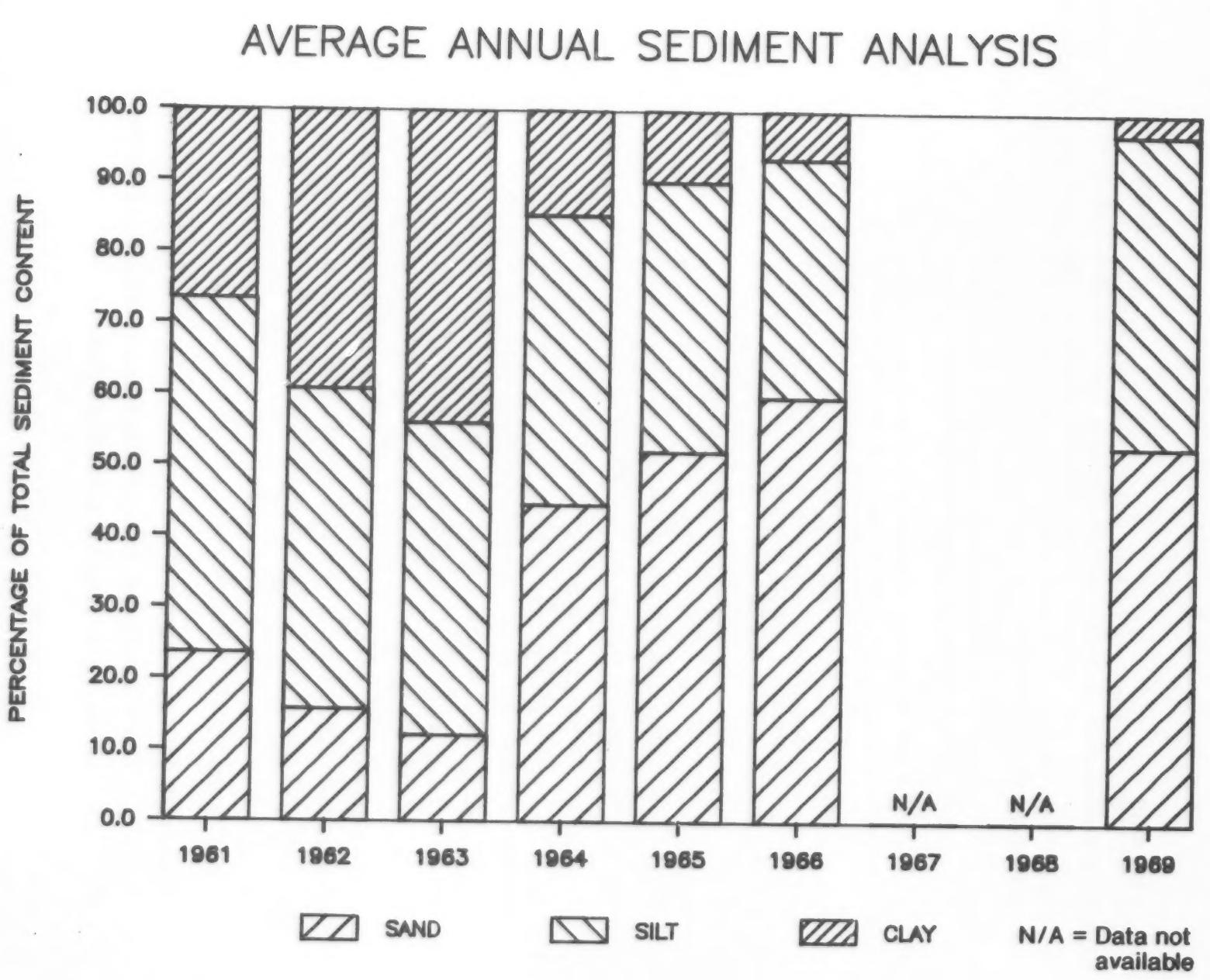


Figure 38 Changes in Content of Suspended Sediment Load, South Saskatchewan River at Saskatoon

SIZE LIMITS

SAND 2.0 to 0.062 mm

SILT 0.062 to 0.004 mm

CLAY 0.00024 to 0.004 mm

LEGEND

▲ this study (PRE- AND POST-DAM

• data points (after Ashmore, 1986)

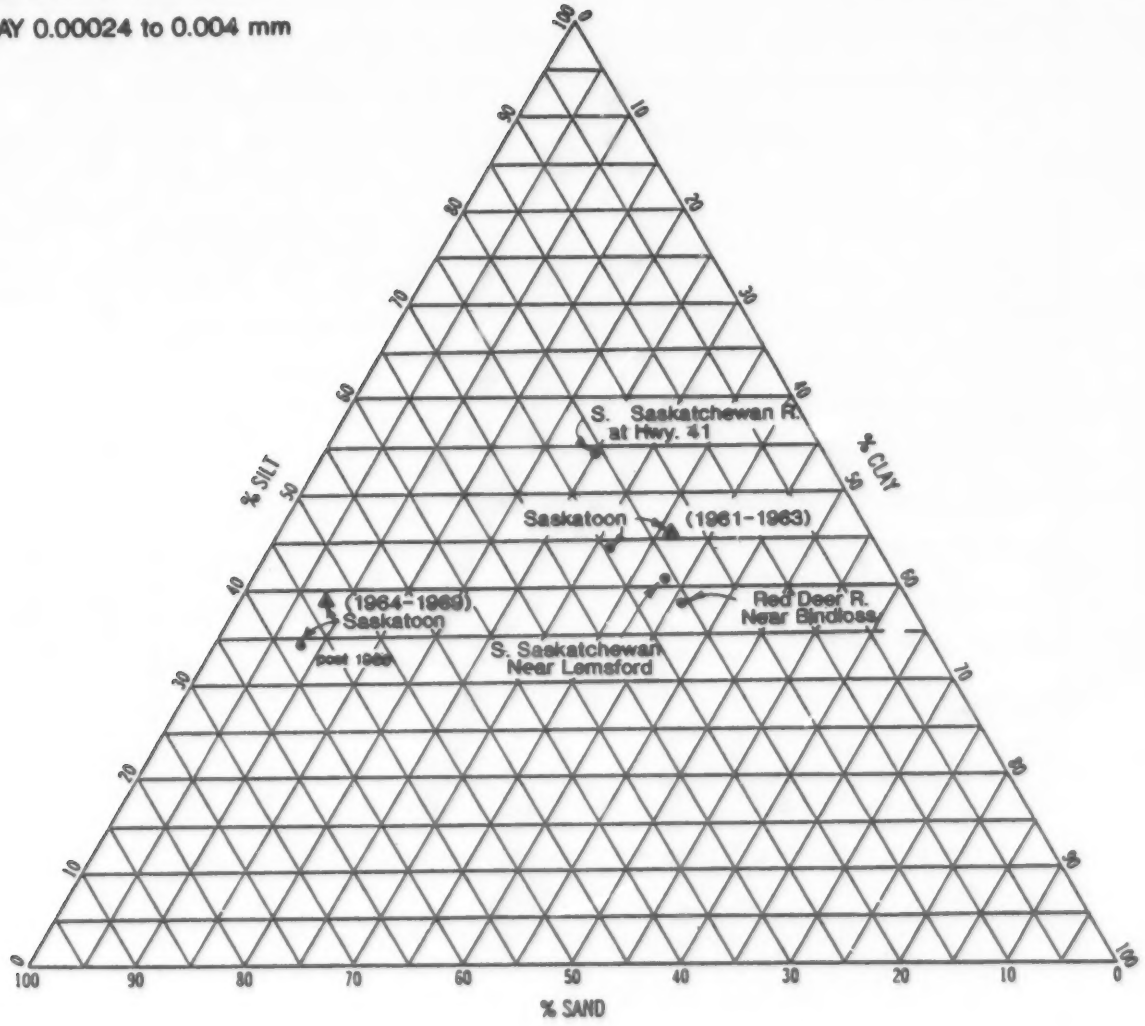


Figure 39 Ternary Diagram of Average Percentage Sand, Silt, and Clay, From Suspended Sediment Samples at Selected Stations in the South Saskatchewan River Basin

all of the wash load at Saskatoon must originate from bank erosion and tributary/overland inflows. If these sources do not contribute silt and clay to the same extent as the upstream basin, then the wash load (silt and clay) must decrease. Indeed, there are no "badland" areas between Saskatoon and Gardiner Dam, such as exist in the lower Red Deer River basin (near Bindloss). Note also in Figure 39, that there is relatively little change in the composition of the suspended sediment between Lemsford and Saskatoon, which substantiates this point.

(ii) The increase in the sand component of the suspended load may be due to degradation occurring downstream of Gardiner Dam. However, the volume or tonnage of material available for transport, based on degradation values published by Yuzyk (1987) appears to be substantially less than the sediment loads passing Saskatoon. Clearly, additional sediment is being picked up for transport through bank erosion (channel migration) and/or tributary sediment inflow, although the latter is thought to be minimal.

With an increase in the proportion of sand and a decrease in the proportion of clay, the average annual sediment grain size has increased (see Figure 40) since closure of the river was initiated in 1964.

Yuzyk (1987) determined that the median surface bed material composition along the thalweg at a test range 1.6 km downstream of Gardiner Dam, has increased by an order of magnitude from 0.24 mm (1968) to 2.5 mm (1985). This coarsening is a result of degradation downstream of the dam which has winnowed out fine sand and smaller particles leaving an armour layer of coarse sand and fine gravels. Furthermore, Yuzyk (1987) determined that for a 53 km long reach downstream of the dam, the previously uniform bed material composition has become more variable with a trend towards coarsening throughout the reach. Similar results have been documented by Rasid (1979).

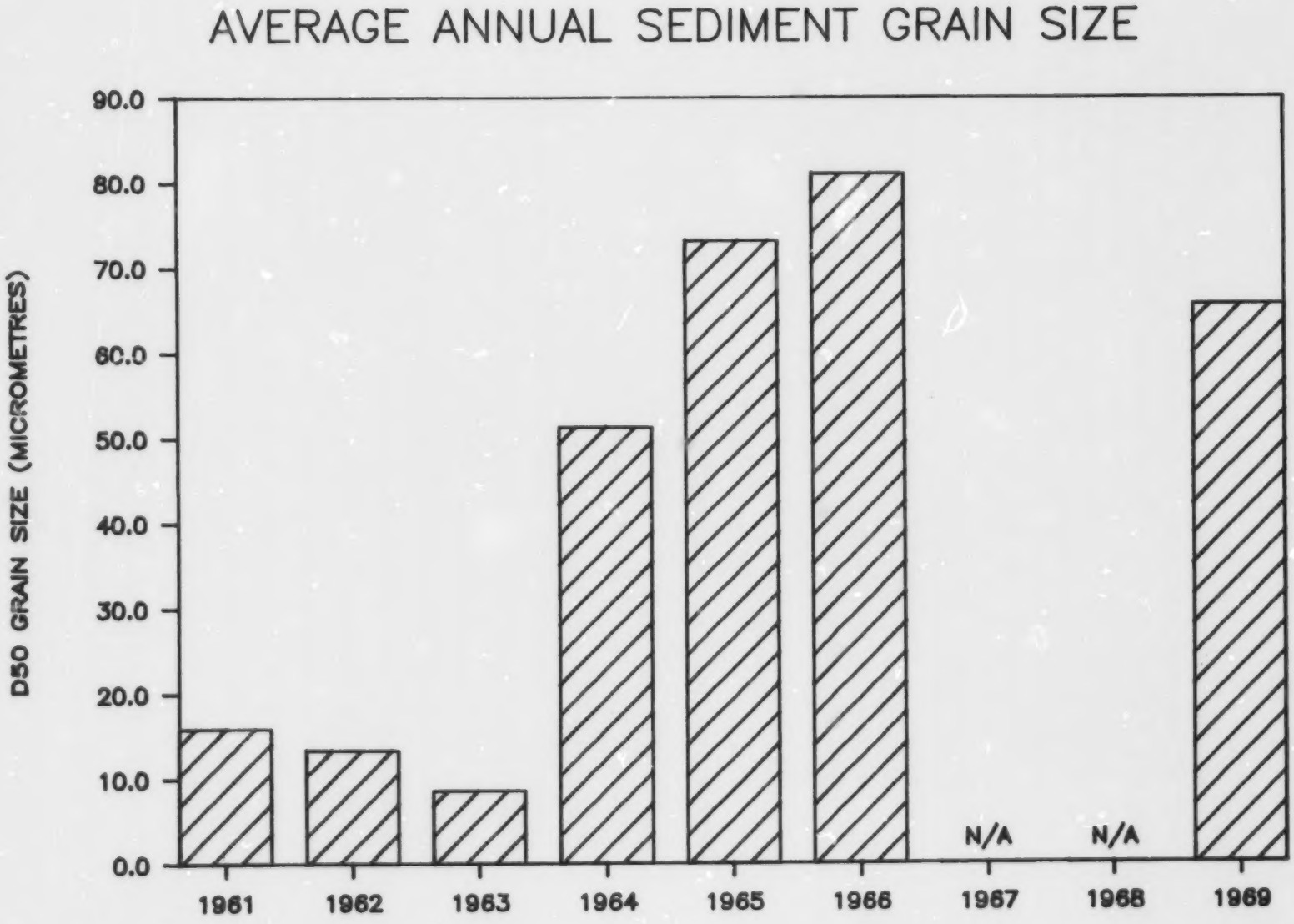


Figure 40 Temporal Changes in Average Annual Suspended Sediment Grain Size

Bed material data for Saskatoon (see Section 4.1.2) indicate that some coarsening has occurred at the 05HG001 gauge site as well, (Figure 41). Furthermore, Ashmore *et al.* (1988), in studying various bed material samples on the South Saskatchewan River at Saskatoon in 1987, determined a mean D_{50} of 0.288 mm. Although this value is slightly lower than the 1971 value of 0.31 mm, it is still larger than pre-dam (before 1964) values.

5.4 SEDIMENT LOADS AND CHANNEL MORPHOLOGY

The impacts of decreased sediment loads due to Gardiner Dam on channel morphology have been examined in detail by Galay *et al.* (1982, 1985), Rasid (1979), and Yuzyk (1987). The most significant findings of these investigations are:

- degradation has progressed for a distance of approximately 8 km below the dam and the bed has been lowered by 1.7 m at a point 1.6 km below the dam between 1967 and 1985
- armouring of the bed has slowed down the degradation process significantly
- at a point 8 km downstream of the dam, water levels have dropped about 0.2 m or 50% of the change in average bed level at this location.
- the degraded channel is quite stable, has entrenched itself into the riverbed and has established a width of approximately 200 m.
- the riverbed slope has flattened below the dam, and in fact has produced an adverse slope along a 2.7 km reach immediately below the dam.

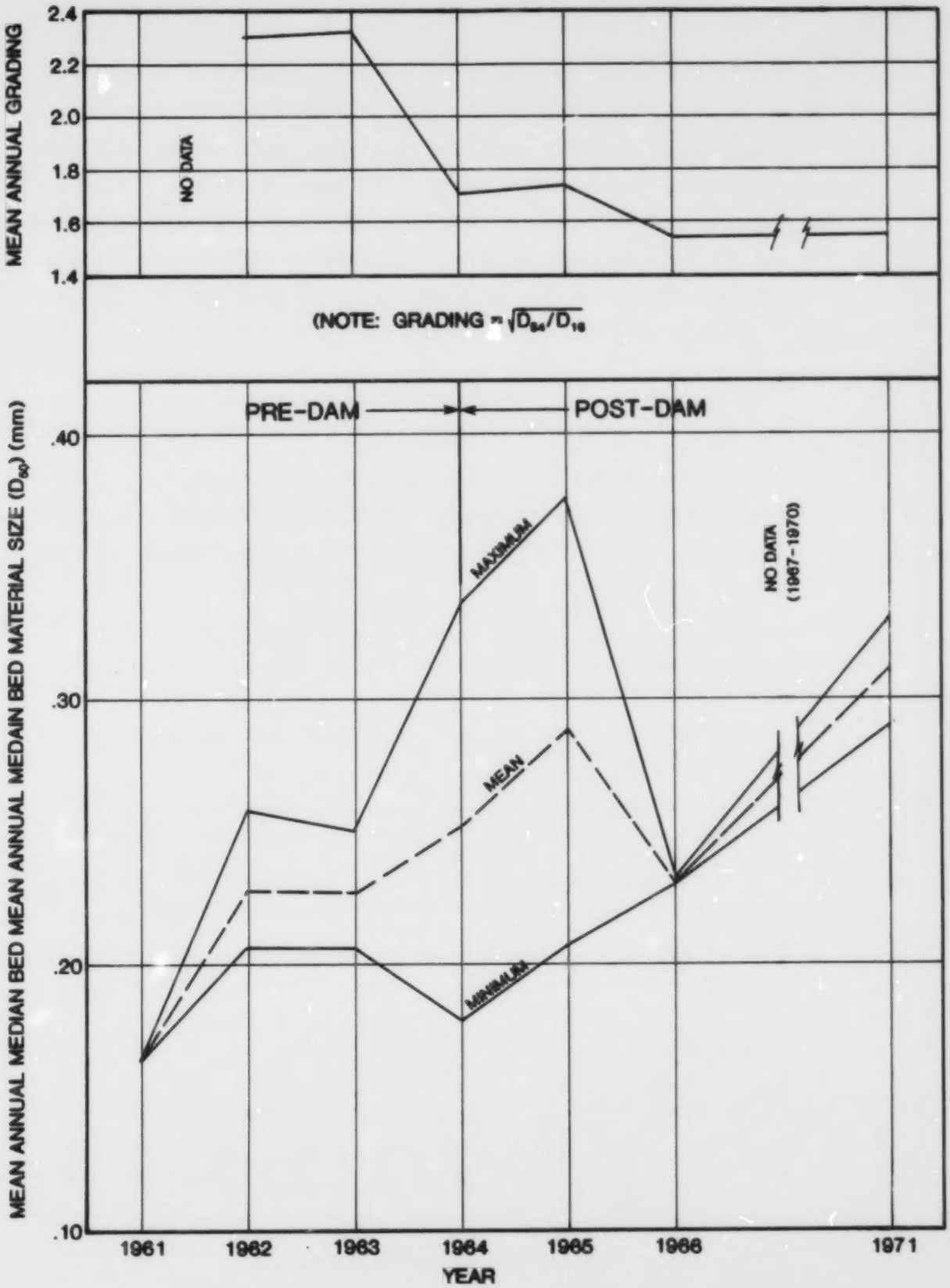


Figure 41 Temporal Changes in Bed Material Characteristics

In the vicinity of the sediment gauging station 05HG001 at Saskatoon, channel characteristics have been defined by comparative cross-sections provided by the City of Saskatoon (Mr. Tony Bellasantos, Engineering Department), and also presented in Environment Canada (1983). These quantitative data have been supplemented by qualitative observations by Gary R.E. Beckstead, P.Eng., of Hardy BBT Limited, accompanied by Mr. Ross Herrington, P.Eng., of Environment Canada during a site visit on September 13, 1988. From this information, the following conclusions have been made:

- Mid-channel islands through the City of Saskatoon have stabilized since the construction of Gardiner Dam.

- Former sand bars have become vegetated.

- Based on discussions with the City of Saskatoon Water Works Division (Mr. Randy Munk, personal communication), sedimentation problems at water intakes have decreased since Gardiner Dam became operational. It is also generally thought that the aggradation upstream of the Saskatoon weir has reached an equilibrium.

- Within the City of Saskatoon and upstream, significant valley wall slumping is occurring, especially along the east bank. This slumping contributes sediment to the South Saskatchewan River channel. Within the City, excavation spoil materials have been placed at the toe of the slopes to stabilize unstable valley wall areas. Valley wall slumping is due largely to geotechnical instabilities in the geologic strata (bentonitic seam). Changes in river water levels or lateral erosion are not major factors.

- In general, little sediment input from local upland supply areas such as Cranberry Flats (sparsely-vegetated sand) and Beaver Creek (unstable valley walls) appears to be reaching the South Saskatchewan River.

- It is thought that most of the sediment passing Saskatoon originates from the river channel (river bed/bars, and banks) between Gardiner Dam and gauge 05HG001.

- Downstream of Saskatoon, the river channel is comprised of a sand bed with boulders. Unlike the reach upstream of the City, there are virtually no mid-channel bars. The potential for sediment input to the river from upland sources appears low because of densely vegetated stable valley walls and a lack of concentrated tributary inflow to the river.

- Comparative river cross-sections from Saskatoon upstream to Gardiner Dam indicate that the river channel is narrowing and entrenching itself into the river bed. Former bare side channel bars are now overgrown with vegetation.

Thus, observations appear to indicate a stabilization of the river channel at Saskatoon due to Gardiner Dam. As noted by other investigators (for example, Environment Canada (1983)), the influence of the weir complicates assessment of river channel changes.

6.0 CODETTE RESERVOIR SEDIMENTATION

Codette Reservoir is situated on the Saskatchewan River, and is formed by the Francois-Finlay Dam near Nipawin. The reservoir lies approximately midway between the confluence of the North Saskatchewan and South Saskatchewan Rivers and the Squaw Rapids Dam (which creates Tobin Reservoir, see Figure 42). The following discussion will evaluate the effects of sediment transport in the South Saskatchewan River on sedimentation in Codette Reservoir.

6.1 SEDIMENT LOADS

Sediment loads on the Saskatchewan River at Codette Reservoir have been estimated for the nine year period between 1963 and 1971, when sediment data is available for the South Saskatchewan River at Saskatoon. Loads from the North Saskatchewan River have been based on measurements taken at Prince Albert (WSC Station 05GG001). Table 12 indicates that since the impoundment of the South Saskatchewan River by Gardiner Dam in the mid 1960s, the majority of the sediment entering Codette Reservoir has been derived from the North Saskatchewan River basin. The data from 1963 and 1964 indicate that prior to impoundment, the majority of the sediment originated from the South Saskatchewan River.

Ashmore (1986) has calculated the seasonal sediment loads for the common period 1963 - 1983 for the stations 05GG001 and 05HG001 to be 2.74×10^6 and 0.600×10^6 tonnes, respectively, (Figure 43). From this, the estimated long-term annual sediment input to Codette Reservoir is 3.34×10^6 tonnes,

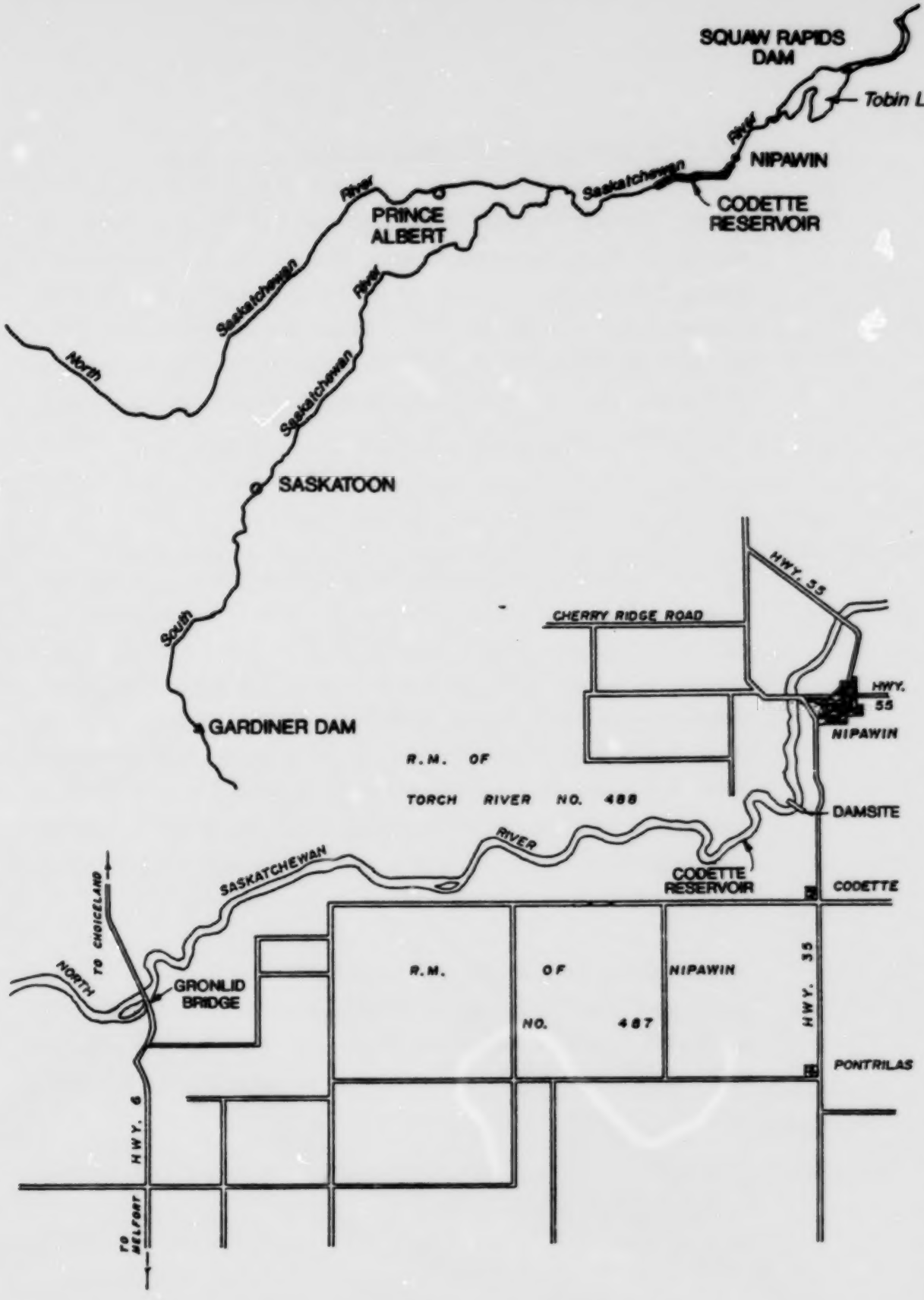


Figure 42 Codette Reservoir Location Plan

TABLE 12
ESTIMATES OF SEDIMENT LOAD
SASKATCHEWAN RIVER AT CODETTE RESERVOIR

Year	North Saskatchewan[1] Load (tonnes)	% of Total	South Saskatchewan[2] Load (tonnes)	% of Total	Total Load[3] (tonnes)
1963	2 580 000	39	4 060 000	61	6 640 000
1964	3 020 000	45	3 760 000	55	6 780 000
1965	9 300 000	79	2 460 000	21	11 760 000
1966	2 810 000	65	1 520 000	35	4 330 000
1967	1 660 000	80	404 000	20	2 064 000
1968	851 000	90	91 900	10	942 900
1969	4 080 000	68	1 950 000	32	6 030 000
1970	2 350 000	91	229 000	9	2 579 000
1971	3 730 000	96	170 000	4	3 900 000
Total	**30 381 000**	**67**	**14 644 900**	**33**	**45 025 900**
Mean	**3 380 000**	**68**	**1 630 000**	**32**	**5 000 000**
Std. Dev.	**2 430 000**		**1 550 000**		**3 260 000**

1. WSC Stn. 05GG001, North Saskatchewan River at Prince Albert.
2. WSC Stn. 05HG001, South Saskatchewan River at Saskatoon.
3. Total of loads from the North Saskatchewan and South Saskatchewan Rivers is assumed to be representative of loads entering Codette Reservoir.

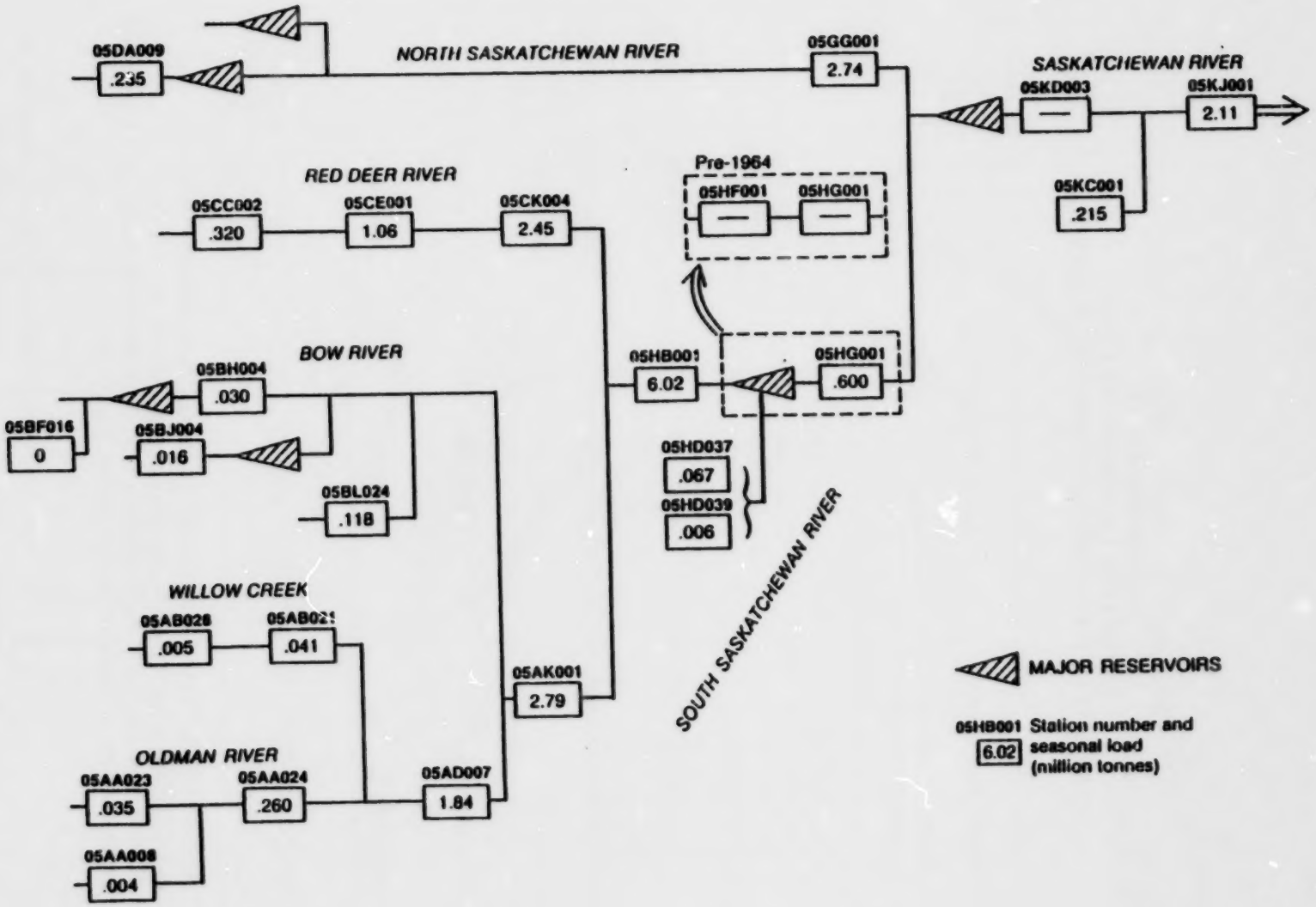


Figure 43 Schematic Diagram of Calculated Seasonal Suspended Sediment Load of the Main Streams in the Saskatchewan River Basin for the Common Period 1964 to 1983 (after Ashmore, 1986)

of which 82% is contributed by the North Saskatchewan River, and 18% from the South Saskatchewan River. The loads indicated in Figure 43, are lower than those presented in Table 12, because of the relatively low loads calculated for the 1972 - 1983 period, and possibly because the loads in Figure 43 are based on seasonal data, whereas loads in Table 12 are based on annual data.

Mean annual sediment inputs to Codette Reservoir in the order of 3×10^6 t may be expected to continue unless a major dam is constructed on the lower North Saskatchewan River. As indicated by Figure 43, the sediment produced in the headwaters areas of the North Saskatchewan River upstream of the Bighorn and Brazeau Dams is small (235 000 t/a at station 05DA009).

6.2 SEDIMENT GRADATION

Ashmore (1986) has presented the average percentage of sand, silt and clay in suspended sediment samples for the Saskatchewan River basin. As discussed in Section 5.3, the impoundment of the South Saskatchewan River by Gardiner Dam has substantially reduced the clay load, and greatly increased the sand load percentage. The percentage of silt has decreased minimally.

Combining this data with Ashmore's analysis of North Saskatchewan River sediment data yields the summary of Saskatchewan River sediment gradation presented in Table 13.

TABLE 13

SUMMARY OF SEDIMENT GRADATION, SASKATCHEWAN RIVER

Stream	Sediment Component Load (tonnes and percent in brackets) Sand	Silt	Clay
North Sask. River	712 400 (26)	1 397 400 (51)	630 200 (23)
South Sask. River	348 000 (58)	204 000 (34)	48 000 (8)
Sask. River	1 060 400 (32)	1 601 400 (48)	678 200 (20)

Although the South Saskatchewan River carries the largest percentage sand load (58%), the overall contribution of any of the size components from this stream is still smaller than that from the North Saskatchewan River. This is because the overall load from the South Saskatchewan River is only 22% of that from the North Saskatchewan River. Nevertheless, the South Saskatchewan River still contributes 33% of the Saskatchewan River's sand load. Thus, it appears the majority of the coarser sediment fractions, which may be dropping out in the upstream portion of the Codette Reservoir, and creating concern about the decreasing freeboard at the Gronlid bridge (Figure 42), are carried by the North Saskatchewan River.

7.0 PROGRAM EVALUATION AND RECOMMENDATIONS

7.1 PROGRAM EVALUATION

The suspended sediment transport characteristics of the South Saskatchewan River at Saskatoon have been generally well-documented by the existing data

base. As discussed in the preceding sections, the following conclusions have been reached:

- The range in the suspended sediment data (daily mean, mean monthly, mean annual) is large.
- The variability of monthly and annual suspended sediment characteristics and totals is well documented.
- Estimates of the mean characteristics of the suspended sediment regime can be improved only slightly with additional data.
- Sufficient suspended sediment data exists for most anticipated engineering needs.
- The sediment data were collected during a period which appears to be representative of the last 77 years of flow history on the lower South Saskatchewan River, despite the recent modifying influences of Gardiner Dam.
- The available data allows a reasonable assessment of the impacts of Gardiner Dam on suspended sediment loads and characteristics and bed material characteristics for the South Saskatchewan River at Saskatoon, despite termination of the full program in 1971, just 4 years after completion of the dam. While this termination may be considered somewhat premature, of equal significance is the short period of pre-dam suspended sediment data (1961-1963). This deficiency makes a thorough assessment of the impacts of Gardiner Dam on suspended sediment loads difficult.
- The suspended sediment data for the South Saskatchewan River at Saskatoon, combined with data for the North Saskatchewan River, are sufficient to estimate sediment loads and characteristics for the Saskatchewan River at Codette Reservoir.

7.2 RECOMMENDATIONS

Based on the analyses conducted on the existing sediment data base for the South Saskatchewan River at Saskatoon, it is recommended that:

- a special sampling program be initiated in conjunction with continuing studies of degradation below Gardiner Dam to measure sediment concentrations and loads and particle size gradations for anticipated peak discharges in excess of 1500 m^3/s. Samples should be taken during the rising and falling limb of a runoff event (say > 800 m^3/s) to document concentration and particle size characteristics during an event. Data on particle size changes during runoff events are not presently available at Saskatoon. Care should be taken to ensure that proper equipment is available for conducting accurate measurements, and that problems do not recur. Measurements should be undertaken from either the Idylwyld (freeway) or Circle Drive bridges.

- additional suspended sediment data be gathered during major flood events (>1500 m^3/s) on the South Saskatchewan River between Saskatoon and Gardiner Dam, say in the vicinity of Outlook. At present, little is known of how the sediment load at Saskatoon is generated, given that the load out of Gardiner Dam is low to nil. These data may improve knowledge of the roles of channel degradation and bank erosion in re-establishing a suspended sediment load at Saskatoon.

- in the event that the weir at Saskatoon is removed, (see Conly and Martz, 1988), sediment load measurements upstream and downstream of the weir be undertaken prior to, during and following removal to monitor impacts on sediment loads. Conly and Martz have estimated that adjustment of the channel would largely take place within one year. In this instance, the Idylwyld (freeway) and Circle Drive bridges would be appropriate monitoring locations.

- The extreme variation in K-factors at Saskatoon should be investigated further to determine the reason(s) for the large standard deviation, and to determine how the data base has been affected by the values used to date.

- The possibility of high sediment loads on the Saskatchewan River could affect the forecast life expectancy of Codette Reservoir and Tobin Lake. This aspect should be investigated in light of information contained in this report. The impact of weir removal at Saskatoon should be considered as well.

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A
PHOTOGRAPHS

Photo 1 - Metal shelter housing W.S.C. gauge 05HG001, located on left (west) bank of South Saskatchewan River approximately 75 m upstream of the weir. (HBT photo 16190-2-20, 1988 09 13).

Photo 2 - Looking west from right (east) bank across South Saskatchewan River towards gauge shelter and the weir. (HBT photo 16190-1-1, 1988).

Photo 3 - Looking upstream from right bank near the WSC gauge. (HBT photo 16190-1-9, 1988).

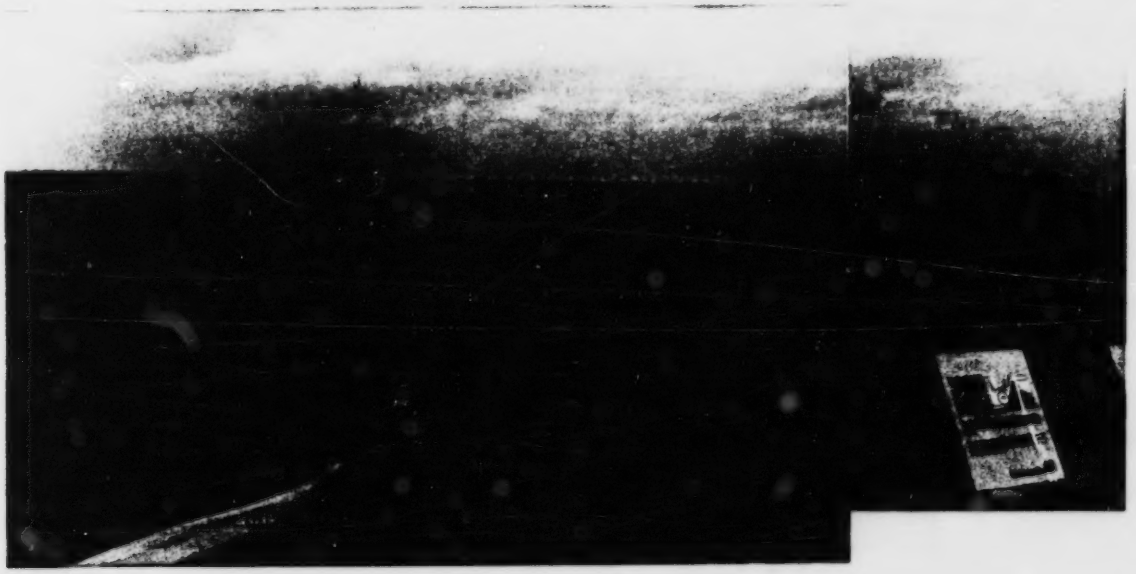


Photo 4 - Looking downstream from the weir along the right bank near the WSC gauge (HBT photo 16190-1-10, 11;1988).

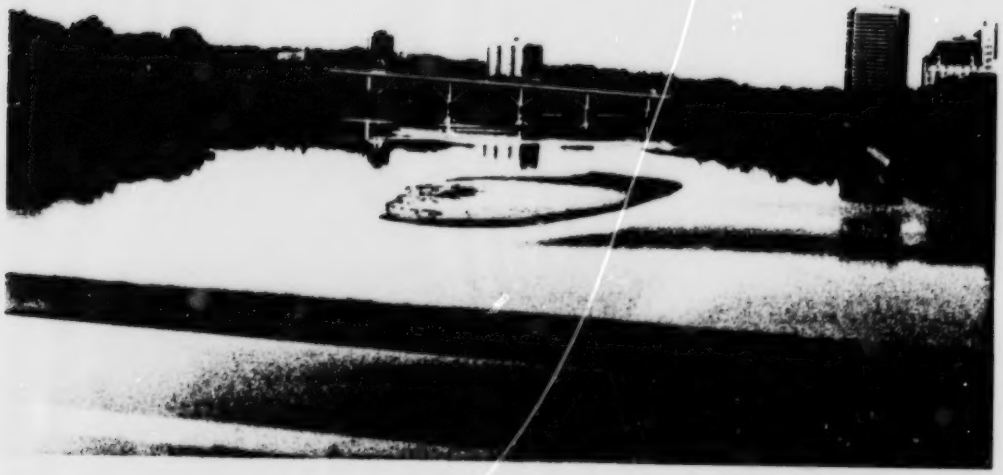
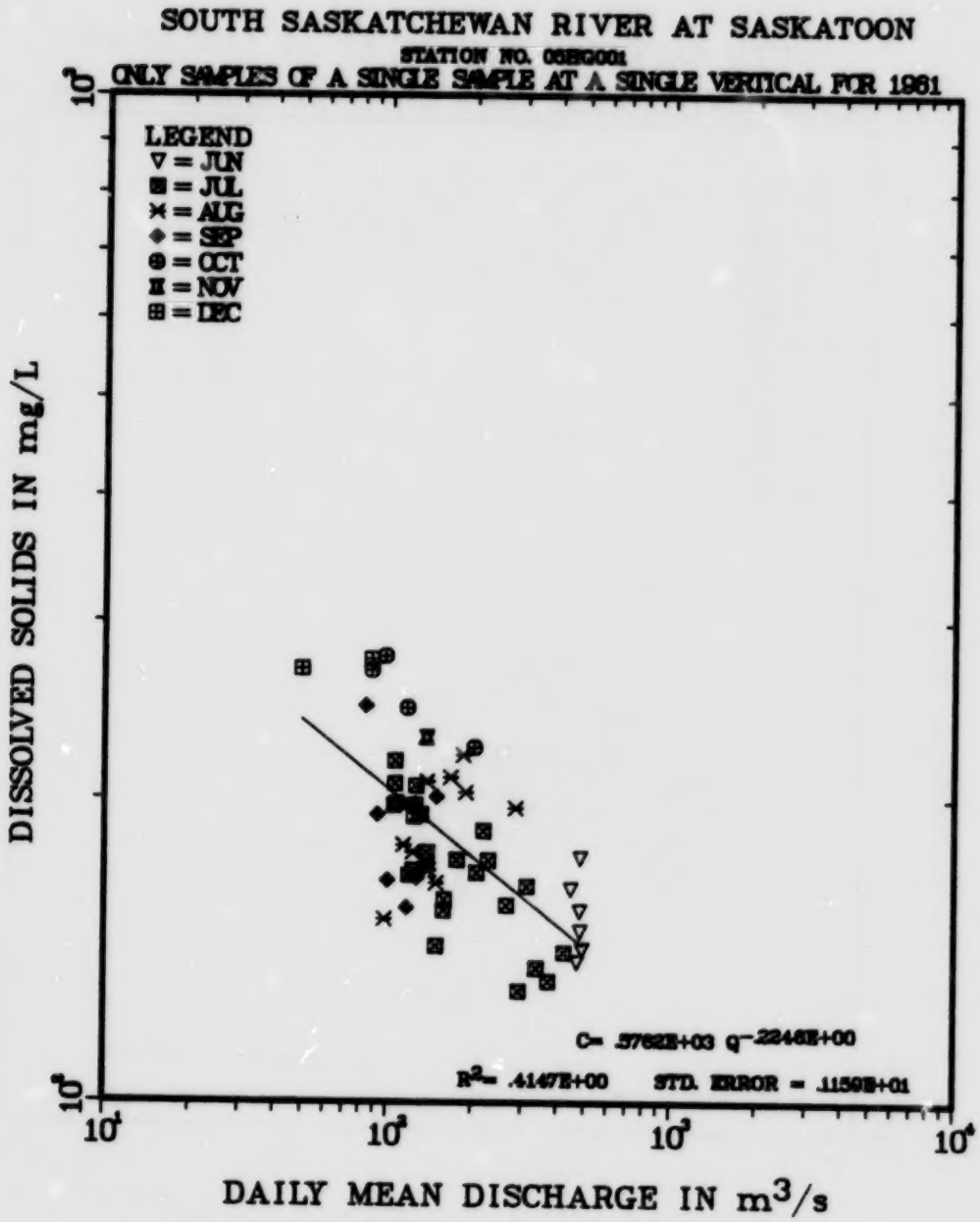
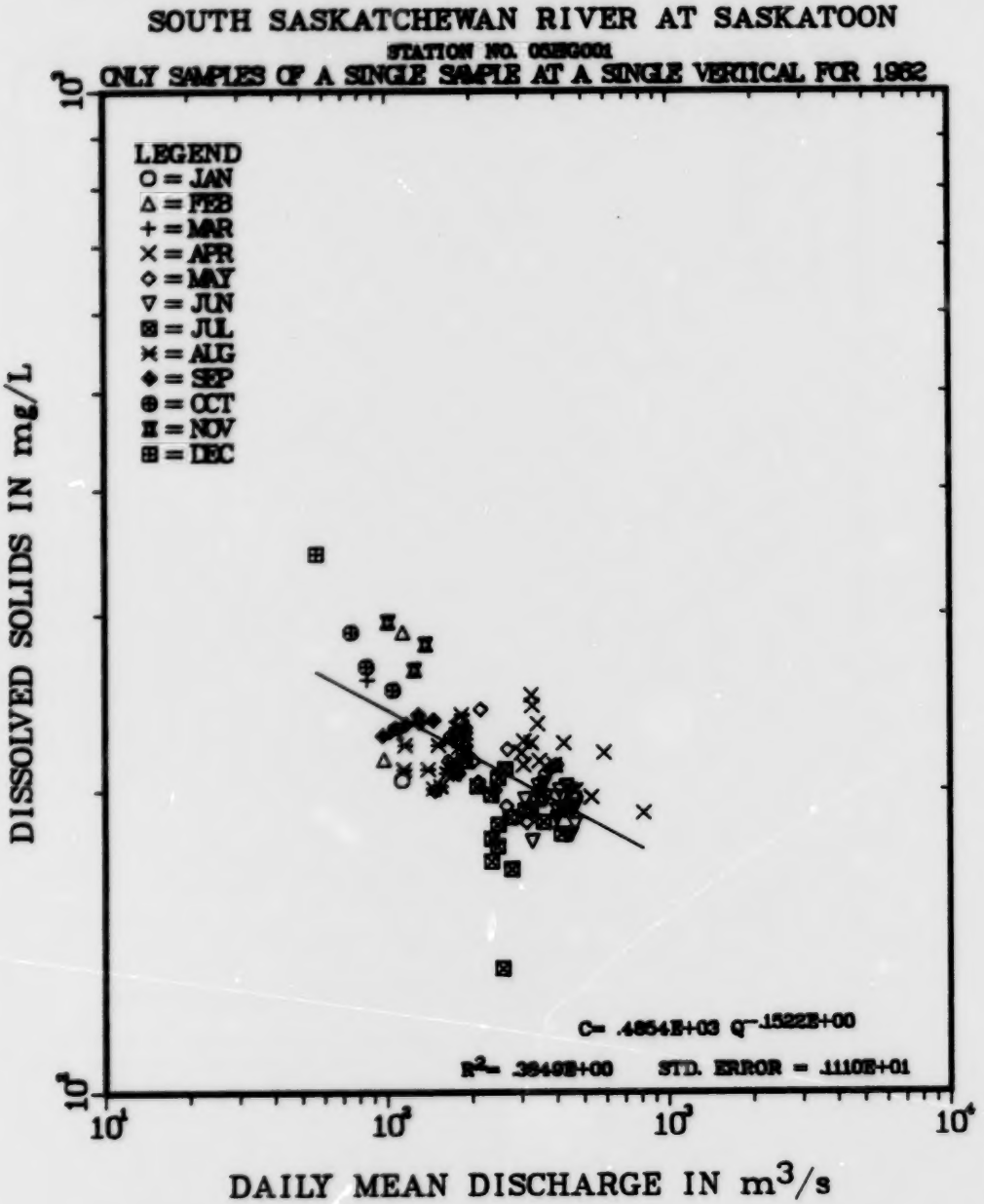


Photo 5 - Looking upstream from University Bridge to Broadway Bridge. Note well-vegetated banks and initial vegetation growth on mid-channel bar. (HBT photo 16190-2-21, 1988 09 13).

Photo 6 - Looking upstream from Traffic Bridge to Idylwyld Bridge. Sediment measurements have been taken from both bridges as a part of the data gathering program. (HBT photo 16190-1-25; 1988 09 13).

B
DISSOLVED SOLIDS DIAGRAMS

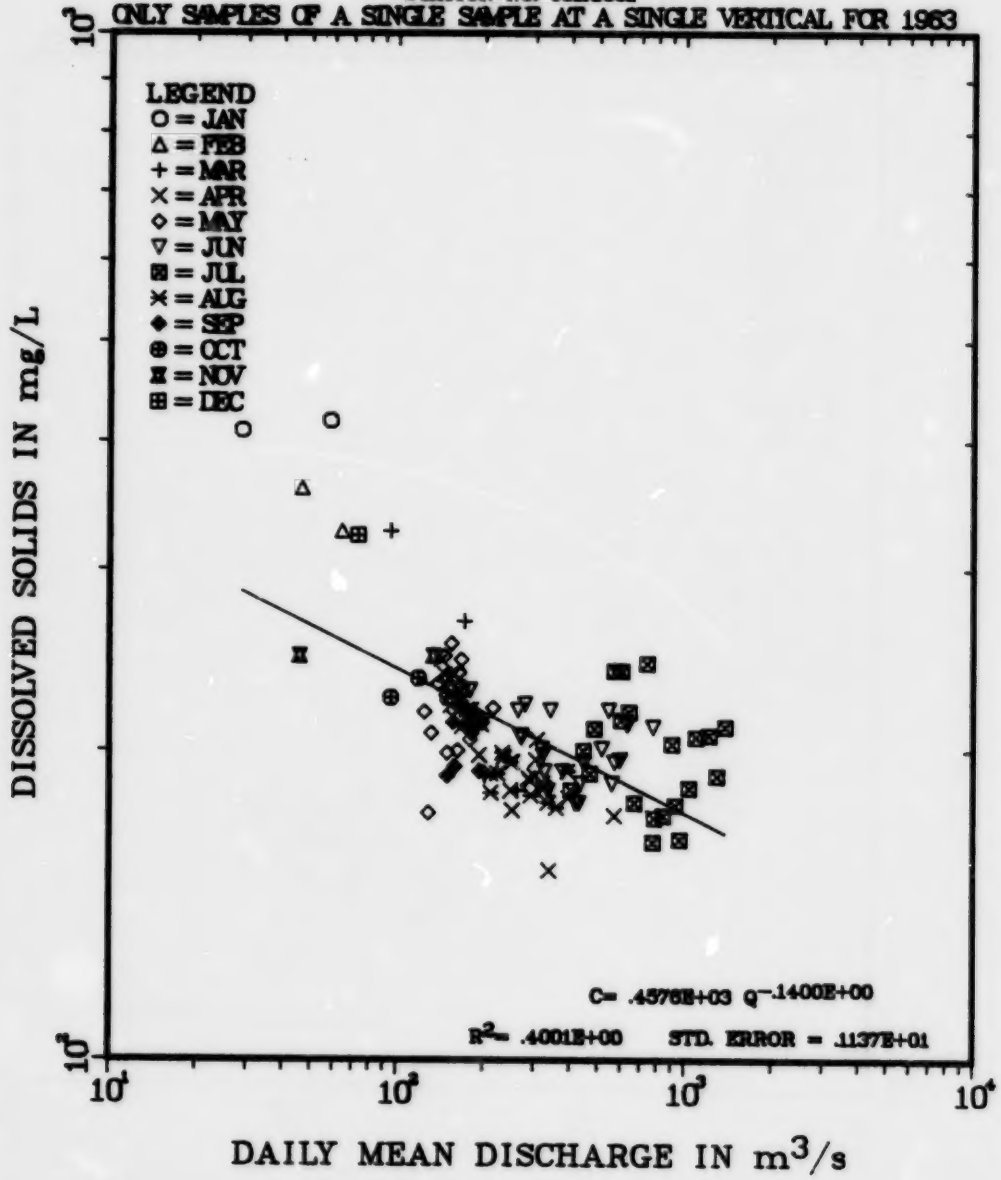

SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05EG001
ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1961
LEGEND
▽ = JUN
■ = JUL
× = AUG
◆ = SEP
⊕ = OCT
⧓ = NOV
⊞ = DEC
C= .5762E+03 q^-.2246E+00
R²= .4147E+00 STD. ERROR = .1159E+01
DISSOLVED SOLIDS IN mg/L
DAILY MEAN DISCHARGE IN m³/s
10³
10²
10¹
10²
10³
10⁴


SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05EG001
ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1982
LEGEND
O = JAN
Δ = FEB
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✕ = AUG
◆ = SEP
⊕ = OCT
⧗ = NOV
⊞ = DEC
C= .4854E+03 Q^-.1522E+00
R²= .3949E+00 STD. ERROR = .1110E+01
DISSOLVED SOLIDS IN mg/L
DAILY MEAN DISCHARGE IN m³/s
10³
10⁴

SOUTH SASKATCHEWAN RIVER AT SASKATOON

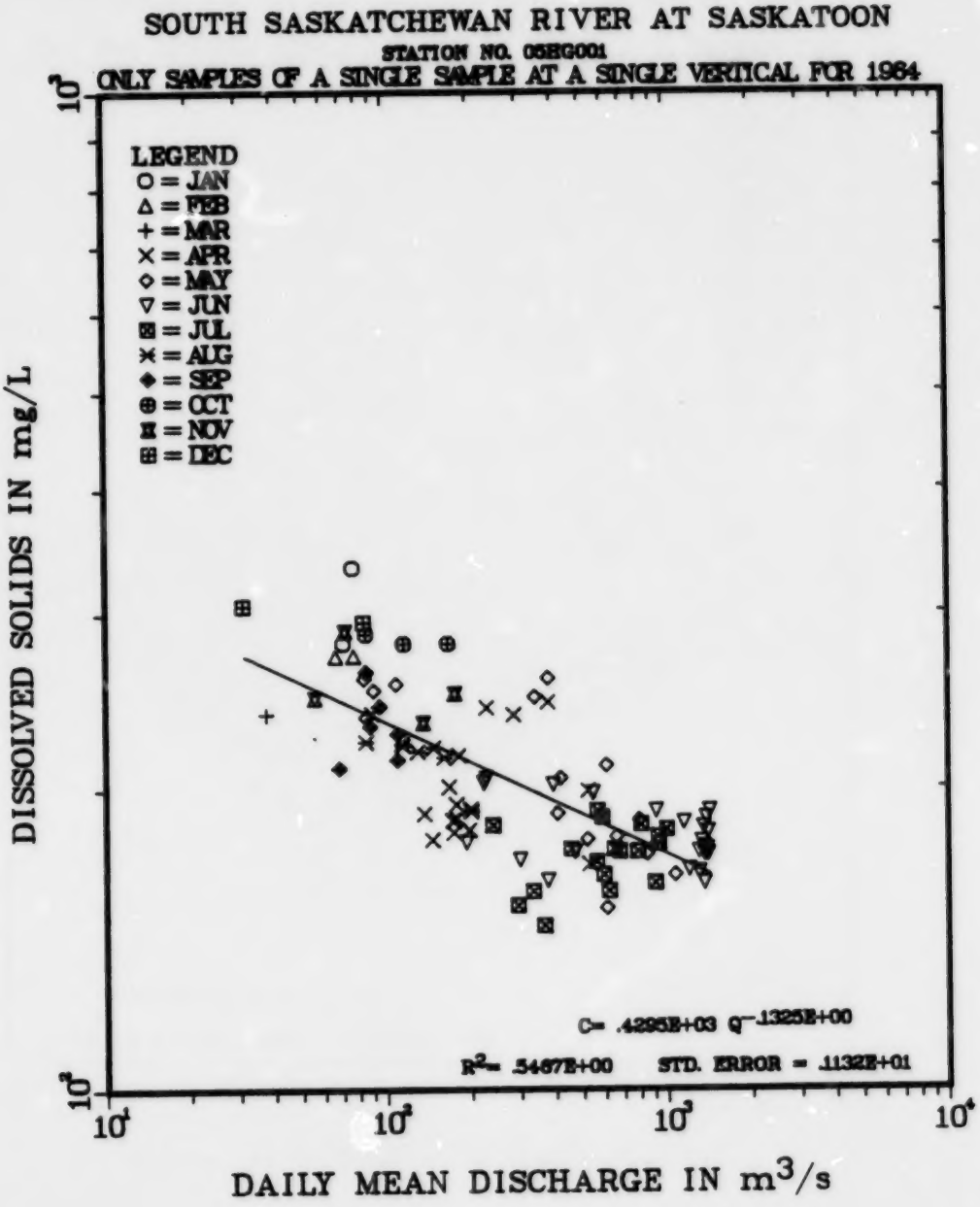
STATION NO. 05HG001

ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1963



DISSOLVED SOLIDS IN mg/L

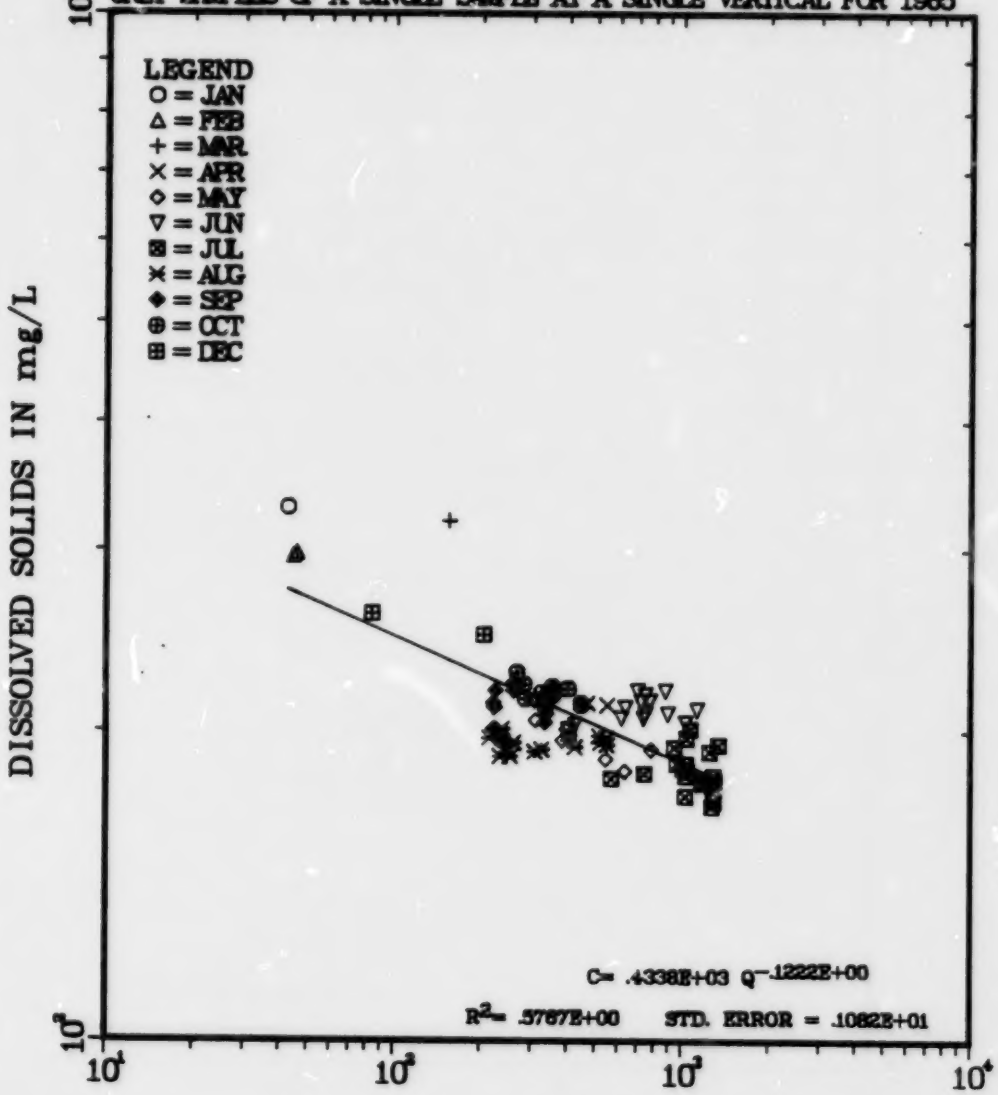
DAILY MEAN DISCHARGE IN m^3/s


SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1984
LEGEND
O = JAN
Δ = FEB
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✳ = AUG
◆ = SEP
⊕ = OCT
⧗ = NOV
⊞ = DEC
C= .4295E+03 Q^-.1325E+00
R²= .5467E+00 STD. ERROR = .1132E+01
DISSOLVED SOLIDS IN mg/L
DAILY MEAN DISCHARGE IN m³/s
10³
10²
10¹
10²
10³
10⁴

SOUTH SASKATCHEWAN RIVER AT SASKATOON

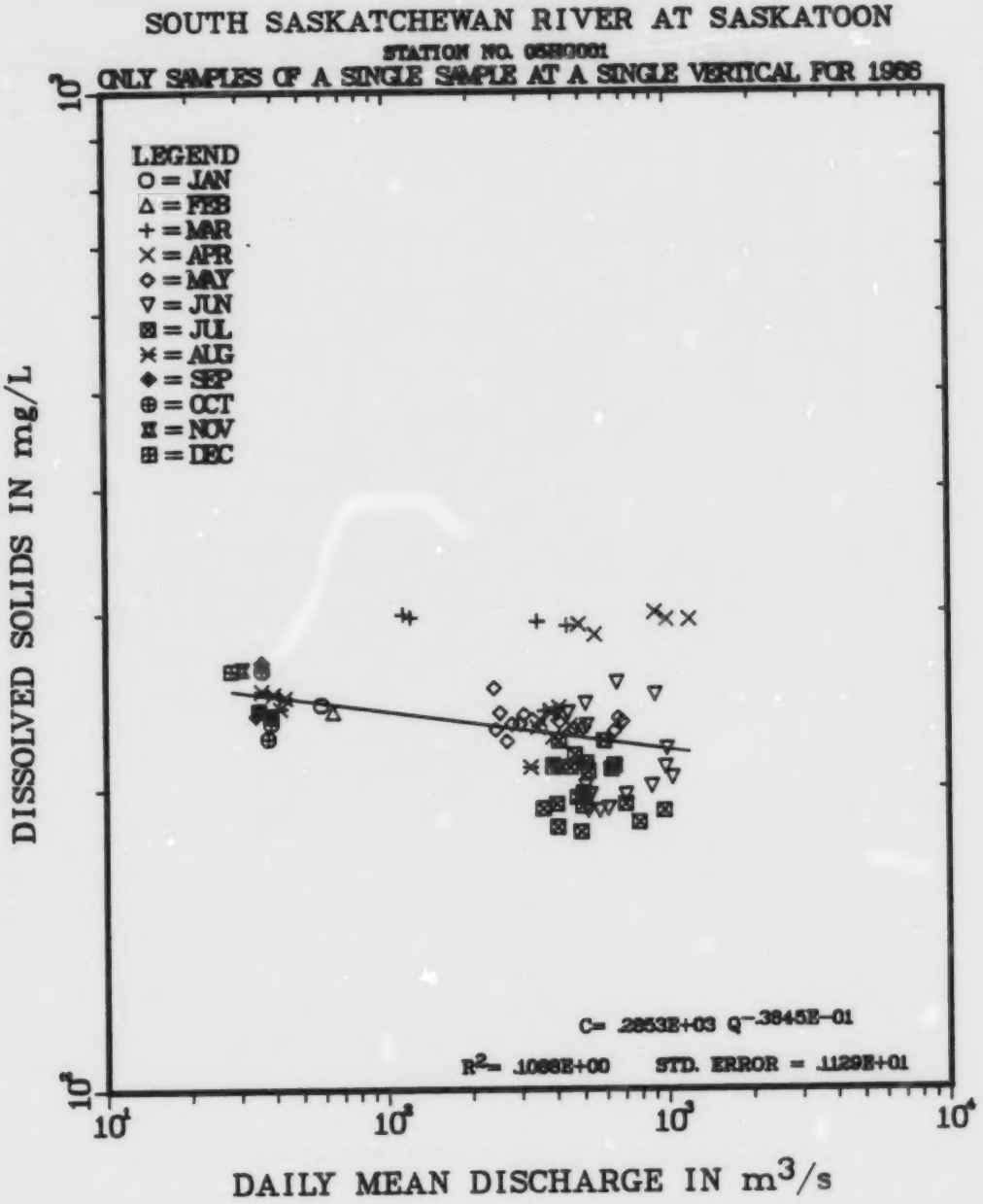
STATION NO. 05HG001

ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1965



DISSOLVED SOLIDS IN mg/L

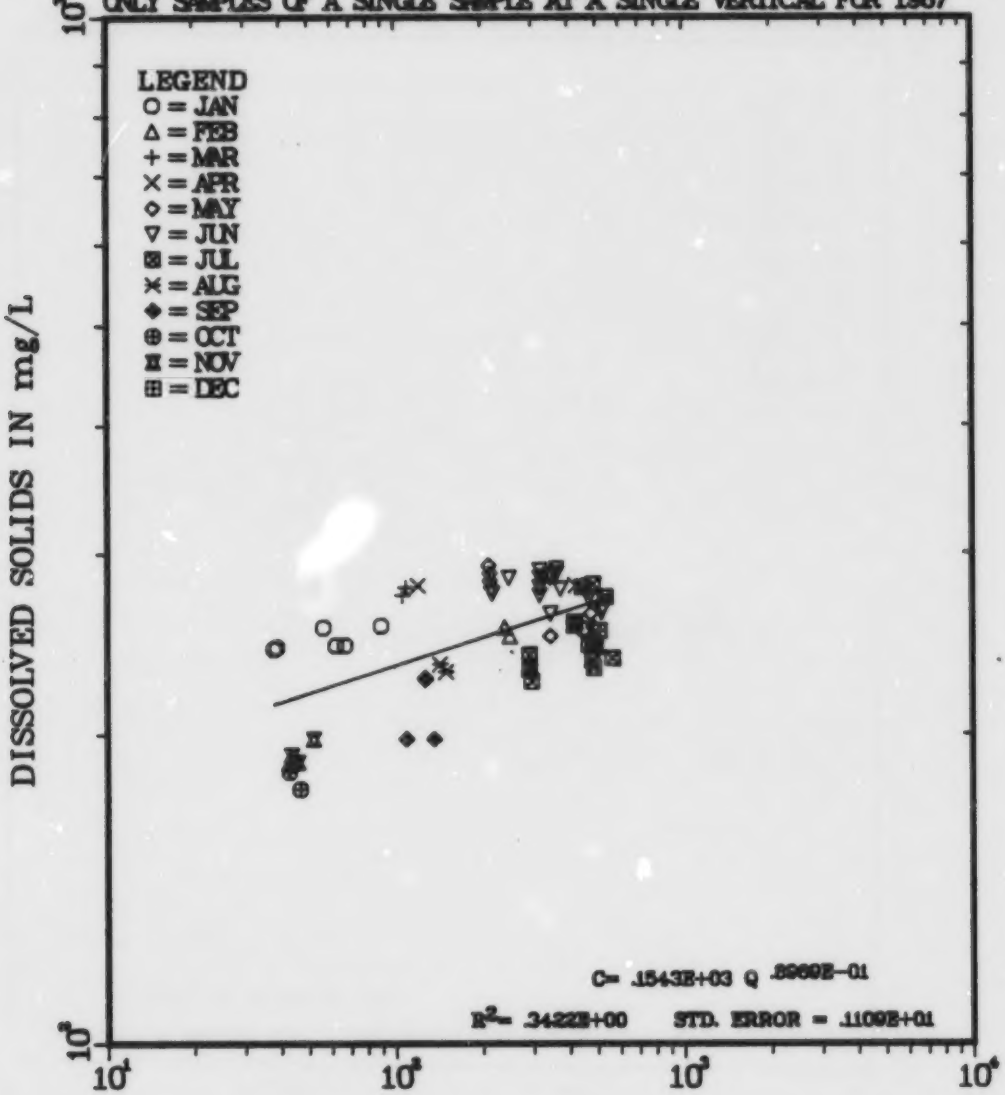
DAILY MEAN DISCHARGE IN m^3/s


SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1966
LEGEND
O = JAN
Δ = FEB
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✳ = AUG
◆ = SEP
⊕ = OCT
⧓ = NOV
⊞ = DEC
C= .2853E+03 Q^-.3845E-01
R²= .1068E+00 STD. ERROR = .1129E+01
DISSOLVED SOLIDS IN mg/L
DAILY MEAN DISCHARGE IN m³/s
10³
10²
10¹
10²
10³
10⁴

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1987



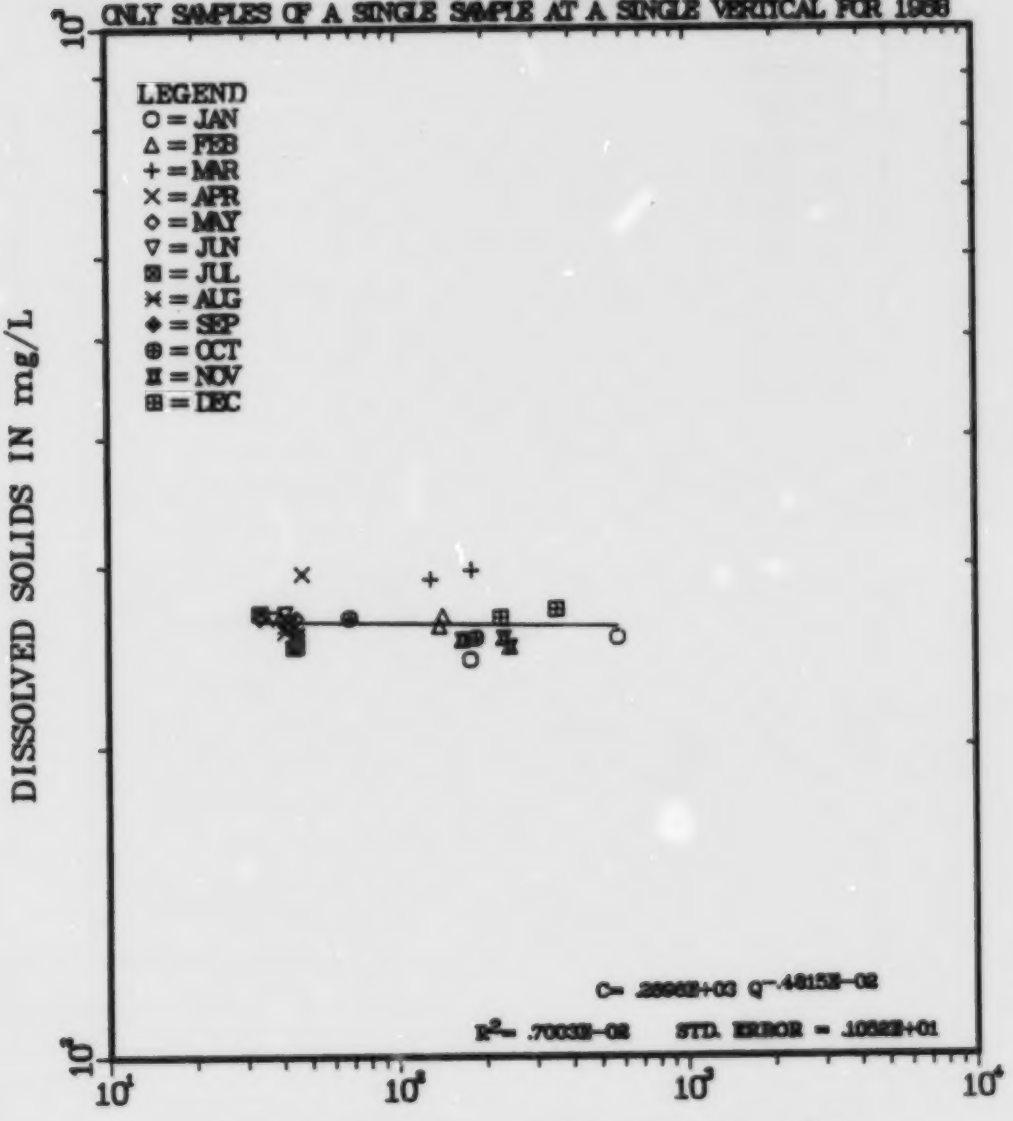
DISSOLVED SOLIDS IN mg/L

DAILY MEAN DISCHARGE IN m^3/s

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05306001

ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1968



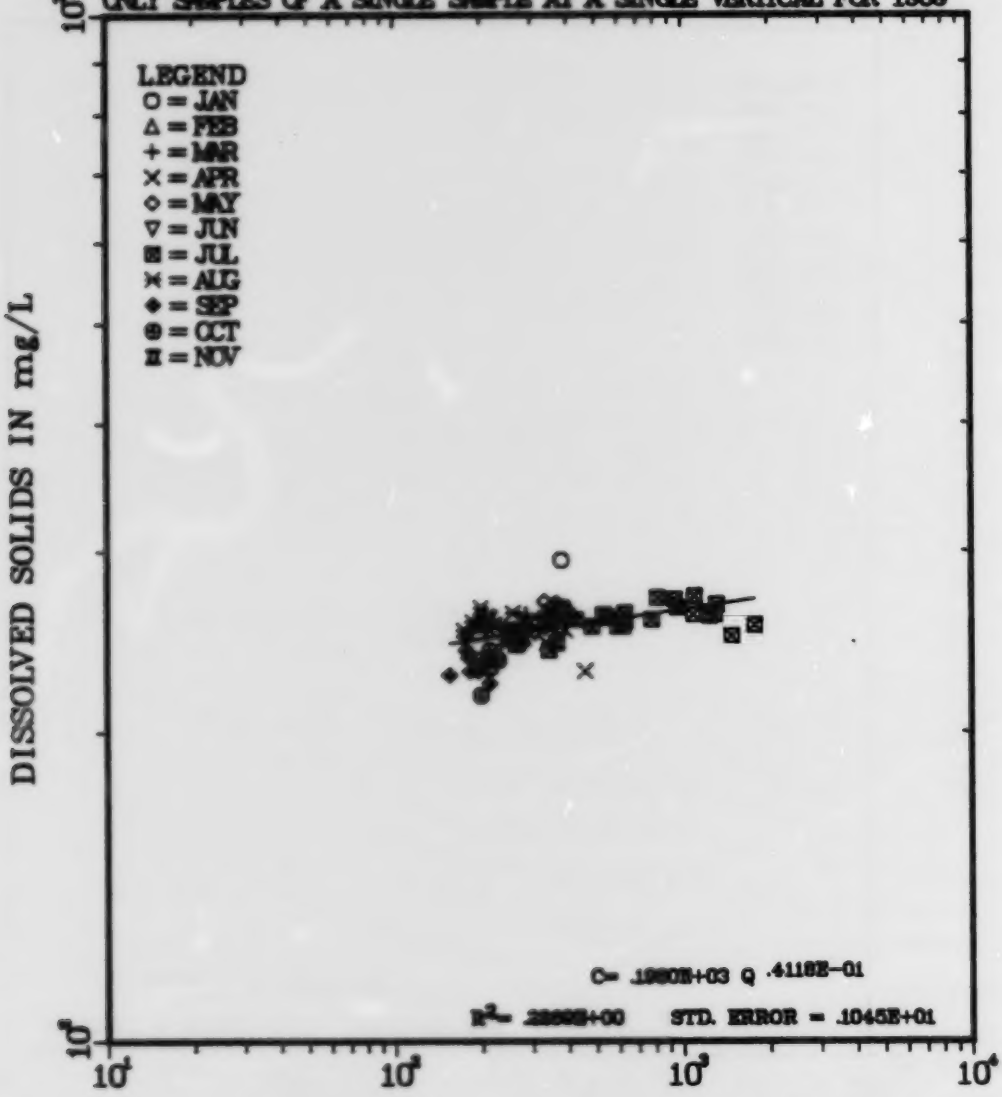
DISSOLVED SOLIDS IN mg/L

DAILY MEAN DISCHARGE IN m^3/s

SOUTH SASKATCHEWAN RIVER AT SASKATOON

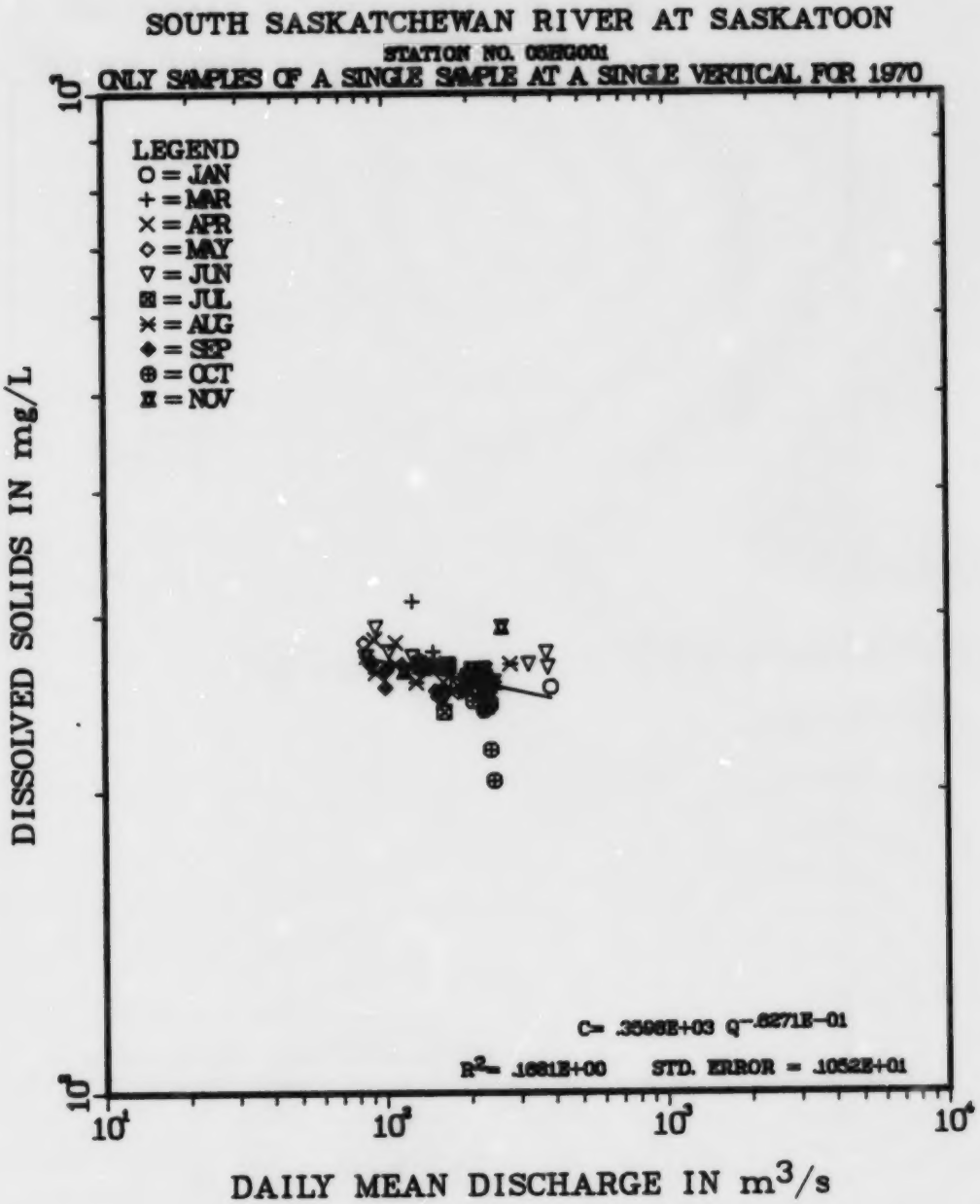
STATION NO. 05EG001

ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1969



DISSOLVED SOLIDS IN mg/L

DAILY MEAN DISCHARGE IN m^3/s


SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLES OF A SINGLE SAMPLE AT A SINGLE VERTICAL FOR 1970
LEGEND
O = JAN
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✳ = AUG
◆ = SEP
⊕ = OCT
⧗ = NOV
C= .3596E+03 Q^-.8271E-01
R²= .1681E+00 STD. ERROR = .1052E+01
DISSOLVED SOLIDS IN mg/L
DAILY MEAN DISCHARGE IN m³/s
10³
10²
10¹
10²
10³
10⁴

C
K - FACTORS

TABLE C-1

"K" FACTORS

(1961 - 1971)

Year	Date	Mean Concentration (mg/L)	K	Remarks
1961	June 29	229	1.00	
	July 12	80	0.89	
	July 25	25	5.0	not used
	August 10	307	0.91	
	August 28	41	1.09	
	September 15	16	1.07	used average of 0.98 for year
	October 5	11	0.92	
1962	April 18	1360	0.93	
	May 7	246	0.98	
	May 30	249	0.84	
	June 6	358	0.96	
	June 18	102	0.86	
	June 27	338	0.96	
	July 13	86	0.90	
	August 7	110	0.94	
	August 16	208	1.05	
	September 11	83	1.01	average of 0.97 for year
	October 3	164	1.04	
	November 1	82	1.00	
	December 6	59	1.00	assumed
1963	March 25	52	1.00	
	April 9	229	0.94	
	April 19	86	1.01	
	April 30	248	1.00	
	May 17	91	1.10	
	May 17	85	1.02	point-integrating sample
	May 29	51	0.96	
	June 6	247	0.90	
	June 20	1239	0.86	point-integrating sample
	June 20	1313	0.91	
	July 2	1457	0.96	
	July 8	2445	0.98	point-integrating sample
	July 8	2320	0.93	
	July 23	472	0.89	
	August 8	506	0.94	
	August 27	111	0.90	
	September 19	58	0.92	average of 0.98 per year
	October 8	47	0.96	
	November 5	42	0.93	
	November 28	11	1.00	estimated; calc. 0.28

TABLE C-1 (continued)

"K" FACTORS

(1961 - 1971)

Year	Date	Mean Concentration (mg/L)	K	Remarks
1964	January 17	11	1.00	estimated; calc. 0.61
	February 25	12	1.00	estimated; calc. 0.67
	April 15	290	1.00	estimated; calc. 0.63
	April 24	402	0.83	not used; calc. error
	May 12	830	0.81	point-integrating
	May 20	648	1.00	point-integrating
	June 1	575	0.96	
	June 16	1157	0.78	0.99 also calc.; average of 0.88 used
	July 8	180	0.88	
	July 30	59	0.92	
	August 19	23	0.85	
	September 15	18	1.00	
	October 19	23	1.00	estimated; calc. 0.85
	November 26	6	1.00	estimated
1965	January 25	13	1.00	estimated; calc. 4.33
	March 26	13	1.00	estimated; calc. 0.69
	April 22	100	0.91	
	April 29	205	0.99	
	May 10	493	0.97	point-integrating
	June 1	76	1.00	estimated; calc. 0.87
	June 14	299	1.00	estimated; calc. 0.83
	June 25	617	0.93	point-integrating
	June 30	618	0.91	
	July 20	485	1.00	estimated; calc. 1.19
	August 5	118	1.00	estimated; calc. 1.24
	September 1	27	1.00	
	October 31	31	1.00	estimated; calc. 0.79
	November 8	16	1.00	estimated; calc. 1.07
	December 1	2	1.00	estimated; calc. 0.50
1966	March 14	7	1.00	estimated; calc. 0.88
	April 8	567	1.04	point-integrating
	April 19	76	1.03	
	May 6	64	1.00	
	May 19	355	.071	
	June 6	223	0.87	
	June 14	476	0.84	
	June 21	313	0.98	
	June 27	197	0.94	
	July 14	264	0.96	
	July 28	42	0.95	

TABLE C-1 (concluded)

"K" FACTORS

(1961 - 1971)

Year	Date	Mean Concentration (mg/L)	K	Remarks
1967	February 27	7	1.00	estimated; calc. 0.64
	April 5	4	1.00	estimated; calc. 1.33
	May 24	20	1.00	estimated; calc. 1.11
	June 8	113	0.92	
	July 17	118	0.99	
	August 22	5	1.00	estimated; calc. 0.83
	December 5	12	1.09	
1968	April 26	6	1.00	estimated; calc. 2.00
	October 17	56	1.09	
	November 21	37	1.00	
1969	May 8	123	0.97	
	June 20	56	0.97	
	July 8	776	0.94	
1970	May 5	163	1.07	
	June 16	86	1.80	
	June 30	279	1.00	
	September 10	58	1.20	
N		97	97	
Mean		280	1.02	
Std. Dev.		439	0.423	

D
PARTICLE SIZE GRADATION DATA

WATER SURVEY OF CANADA — SOUTH SASKATCHEWAN RIVER AT SASKATOON — STATION NO. 05HG001

12/09/88 PAGE 1

SEDIMENT SURVEY SECTION

DEPTH INTEGRATING PARTICLE SIZE ANALYSIS OF SUSPENDED SEDIMENT

SAMPLE DATE	IDENTIFIER TIME	DISCHARGE (M3/S)	CONC (MG/L)	PERCENT FINER THAN INDICATED SIZE, IN MICROMETRES 2	4	8	16	31	62	125	250	500	1000	2000	TOTAL D50	TOTAL GDG	SAND D50	SAND GDG	PERCENT CLAY	PERCENT SILT	PERCENT SAND
JUN 24 1961	1130	481 H	390 K	15	22	36	52	65	73	83	91	96	100		14.6	7.6	155.2	2.3	22	51	27
JUN 25 1961	1120	479 H	370 K	08	17	32	45	58	67	80	92	99	100		21.3	6.3	144.6	1.9	17	50	33
JUN 26 1961	1045	447 H	345 K	23	27	38	51	65	74	84	92	95	100		15.1	*	148.6	2.6	27	47	26
JUN 27 1961	1045	430 H	325 K	11	21	28	41	57	72	84	93	97	100		22.6	6.5	144.7	2.1	21	51	28
AUG 10 1961	1500	258	305 R	38	46	52	64	82	96	99	100				5.9	*	79.7	1.6	46	50	4
APR 18 1962	1600	609	1 400 R	14	21	34	49	65	74	80	86	88	92		16.8	8.5	312.7	*	21	53	26
JUN 27 1962	1050	430	340 R	15	22	43	59	72	81	91	96	98	99		9.8	6.0	121.5	2.1	22	59	19
AUG 16 1962	1530	166	210 R	61	75	91	95	96	98	99	100				*	*	125.0	1.8	75	23	2
MAR 25 1963	1730	206	50 R	49	57	65	70	76	79	88	96	97	98		2.2	*	135.0	2.0	57	22	21
JUN 6 1963	1500	270	230 R	10	20	31	47	67	88	93	97	99	100		17.7	4.1	159.7	2.1	20	68	12
JUL 2 1963	1530	663	1 560 R	37	48	64	76	83	89	95	98	99	100		4.4	*	117.6	2.0	48	41	11
JUL 8 1963	1130	1 560	2 430 R	16	23	35	48	61	76	88	95	98	99		17.9	6.9	125.0	2.0	23	53	24
JUL 23 1963	1530	470	450 R	28	38	56	70	78	86	94	98	99	100		6.5	*	113.8	1.7	38	48	14
AUG 8 1963	1500	348	480 R	56	64	77	89	95	98	99	100				*	*	125.0	1.8	64	34	2
SEP 19 1963	1430	150 H	55 R	46	58	81	96	98	99	100					2.7	*	79.2	1.2	58	41	1
APR 13 1964	1230	530 H	775 K	03	07	11	18	28	44	65	87	98	100		76.3	4.0	155.4	1.9	7	37	56
APR 15 1964	1600	476	290 R	08	11	20	34	52	70	86	96	99			29.0	4.2	119.3	1.7	11	59	30
MAY 5 1964	1230	419 H	360 K	02	06	12	20	32	50	74	92	99	100		62.0	3.8	128.6	1.8	6	44	50
MAY 20 1964	1630	677	650 R	21	33	47	54	62	73	83	92	96	98		9.7	*	160.8	2.3	33	40	27
JUN 1 1964	1500	779	575 R	13	20	30	36	42	52	68	81	90	95		54.9	10.6	178.1	2.6	20	32	48
JUN 16 1964	1600	1 290	1 160 R	08	11	15	20	27	44	63	81	93	97		75.4	5.5	178.5	2.2	11	33	56
APR 29 1965	1450	394	205 R	23	28	35	45	65	84	95	98	100			19.8	*	98.6	1.6	28	56	16
JUN 14 1965	1500	699	300 R	04	07	10	17	28	52	87	99	100			59.4	2.8	98.9	1.4	7	45	48
JUN 24 1965	1430	1 130 H	480 R	03	04	07	10	18	36	66	90	98	100		88.7	2.7	130.5	1.7	4	32	64
JUN 25 1965	1445	1 280	615 R	05	06	08	12	21	40	68	92	98	100		81.0	2.9	131.1	1.7	6	34	60
JUN 30 1965	1500	1 470	620 R	04	05	07	10	16	28	53	80	94	98		116.8	3.0	161.1	1.9	5	23	72
APR 3 1966	1900	906 H	670 K	01	04	07	13	23	40	73	97	100			80.1	2.8	118.3	1.5	4	36	60
APR 11 1966	1900	620 H	210 K	09	12	17	25	36	53	87	99	100			56.4	4.1	102.6	1.4	12	41	47
MAY 17 1966	1900	464 H	150 K	17	19	23	30	45	78	99	100				35.5	*	77.9	1.2	19	59	22
MAY 19 1966	1135	637	355 R	07	10	15	23	36	66	95	100				45.4	3.2	86.9	1.3	10	56	34
MAY 19 1966	1140	637	500 K	07	08	10	17	28	51	92	99	100			60.7	2.7	93.8	1.3	8	43	49
MAY 20 1966	1830	691 H	365 K	03	04	07	14	23	40	81	96	98	99		76.6	2.7	104.8	1.5	4	36	60
JUN 6 1966	1415	620	225 R	07	08	11	17	26	47	85	98	100			66.2	2.9	101.5	1.4	8	39	53
JUN 8 1966	2000	903 H	570 K	03	04	06	10	17	35	71	95	97	98		86.2	2.4	117.6	1.5	4	31	65
JUN 9 1966	1900	1 090 H	630 K	03	03	04	09	16	33	70	95	98	99		89.1	2.3	117.9	1.5	3	30	67
JUN 10 1966	1230	1 150 H	730 K	03	04	05	07	13	28	79	95	98	99		88.7	1.9	104.3	1.4	4	24	72
JUN 11 1966	0830	1 140 H	670 K	02	03	04	08	15	31	69	93	97	98		92.3	2.2	118.3	1.6	3	28	69
JUN 11 1966	1330	1 140 H	700 K	02	03	04	06	12	30	69	95	99	100		92.5	2.1	117.4	1.5	3	27	70
JUN 12 1966	1400	1 120 H	620 K	03	04	06	10	18	36	83	95	98	99		80.0	2.2	101.8	1.4	4	32	64
JUN 13 1966	1215	1 260 H	750 K	06	07	08	12	17	30	59	87	94	98		103.8	2.9	141.4	1.8	7	23	70

DISCHARGE FOOTNOTE SYMBOLS
BLANK - INSTANTANEOUS
H - DAILY MEAN

CONCENTRATION FOOTNOTE SYMBOLS
R - SAMPLES COLLECTED IN SEVERAL VERTICALS
K - SAMPLE(S) COLLECTED IN A SINGLE VERTICAL

GDG (GRADING) = SQUARE ROOT (D84/D16)
* - UNABLE TO COMPUTE DUE TO INSUFFICIENT DATA

WATER SURVEY OF CANADA
12/09/88 PAGE 2
SEDIMENT SURVEY SECTION

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

DEPTH INTEGRATING PARTICLE SIZE ANALYSIS OF SUSPENDED SEDIMENT

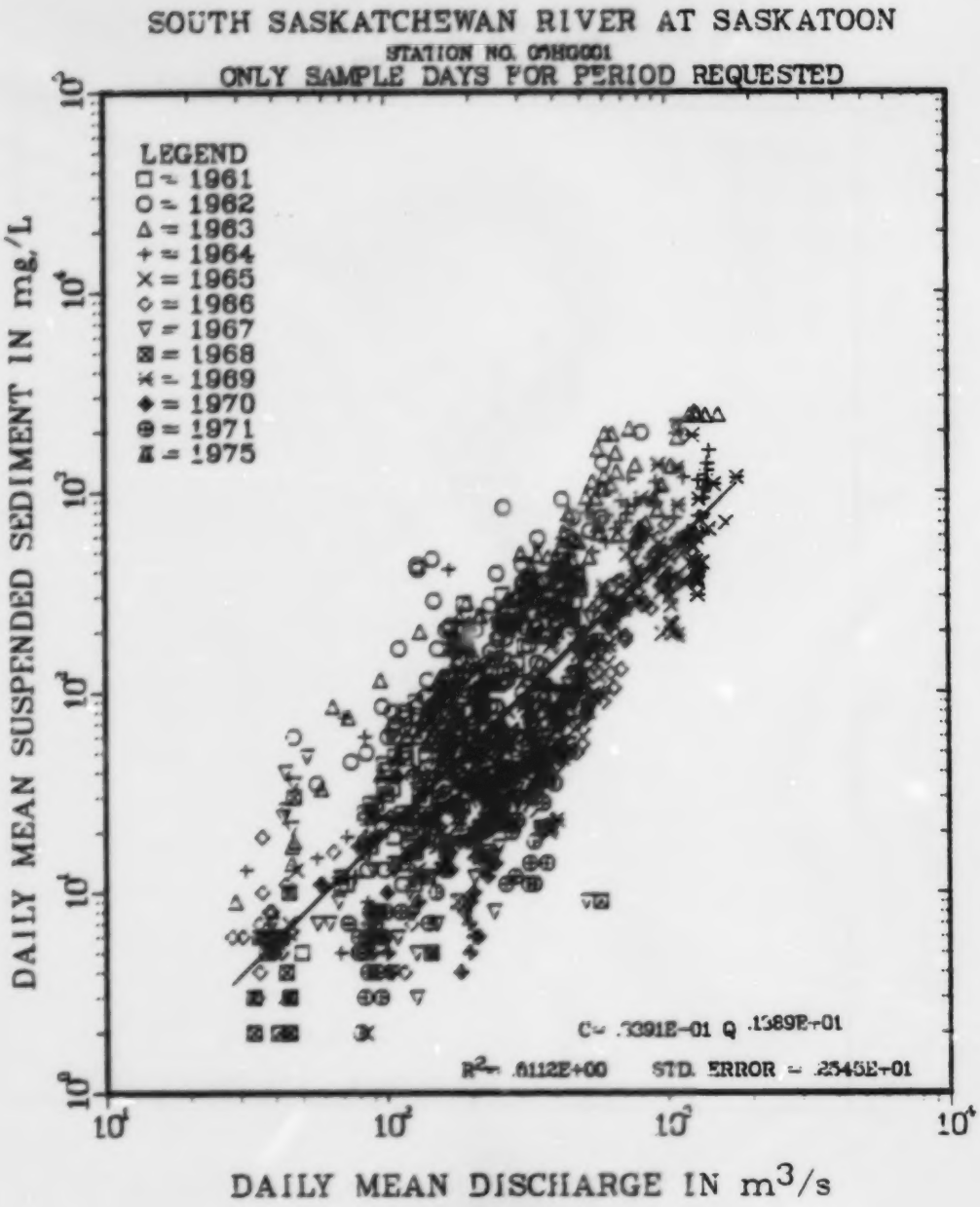
SAMPLE IDENTIFIER DATE	TIME	DISCHARGE (M3/S)	CONC (MG/L)		PERCENT FINER THAN INDICATED SIZE, IN MICROMETRES 2	4	8	16	31	62	125	250	500	1000	2000	TOTAL D50	TOTAL GDG	SAND D50	SAND GDG	PERCENT CLAY	PERCENT SILT	PERCENT SAND
JUN 14 1966	1530	1 260	475	R	04	05	06	09	13	26	57	83	95	98		109.2	2.5	141.0	1.9	5	21	74
JUN 21 1966	1645	847	315	R	05	06	08	11	17	25	51	82	94	98		122.7	3.1	156.1	1.8	6	19	75
JUN 27 1966	1240	711	195	R	06	08	11	16	24	40	73	92	97	99		80.0	3.2	118.1	1.6	8	32	60
JUL 14 1966	1245	813	265	R	07	08	11	16	22	35	65	92	98	99		92.7	3.4	131.2	1.6	8	27	65
JUL 3 1969	1830	937 H	1 680	K	02	03	05	09	20	47	85	99	100			65.6	2.2	99.8	1.4	3	44	53

DISCHARGE FOOTNOTE SYMBOLS
BLANK - INSTANTANEOUS

CONCENTRATION FOOTNOTE SYMBOLS
R - SAMPLES COLLECTED IN SEVERAL VERTICALS

GDG (GRADING) = SQUARE ROOT (D84/D16)

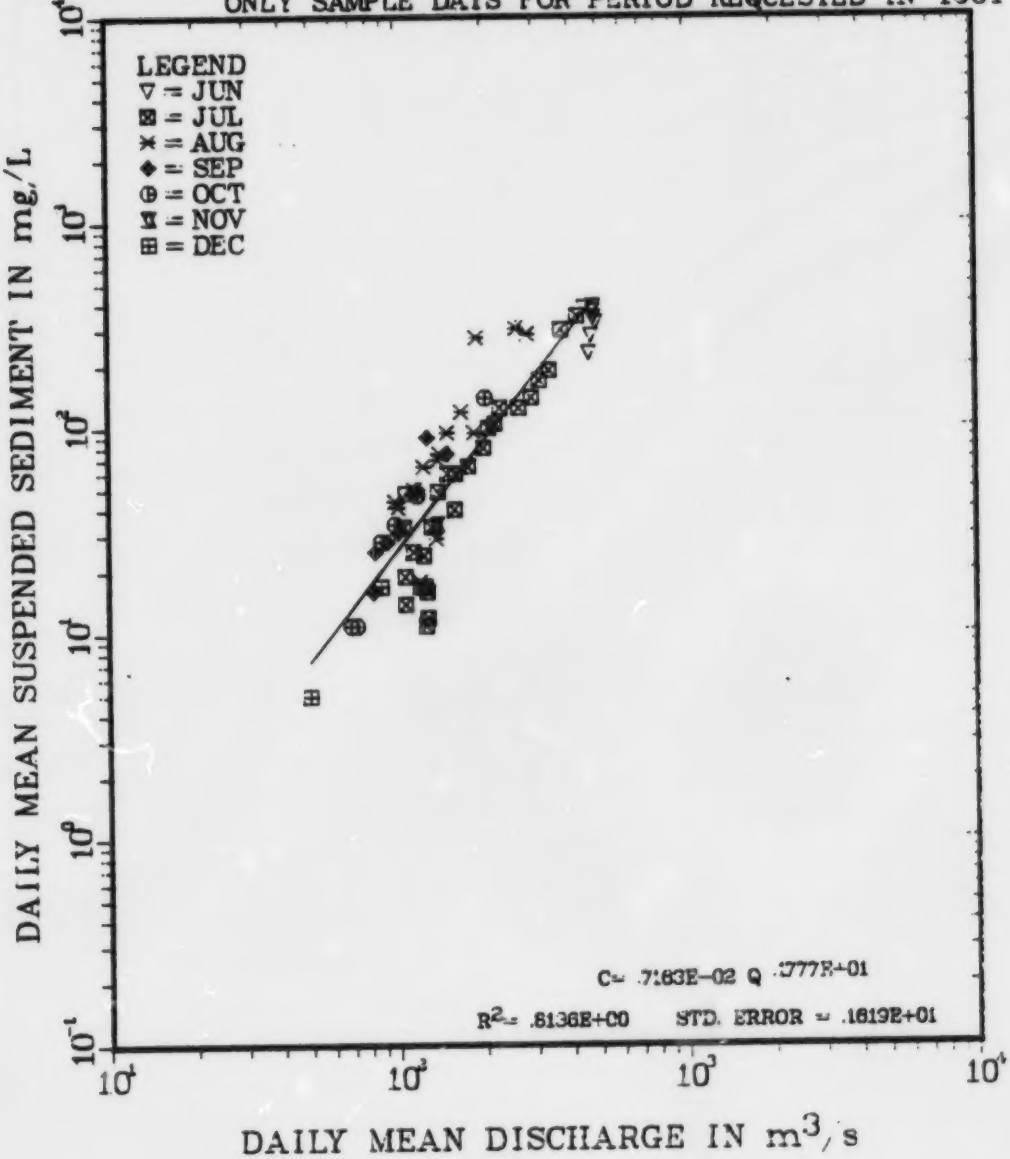
E
ANNUAL SUSPENDED SEDIMENT DATA PLOTS

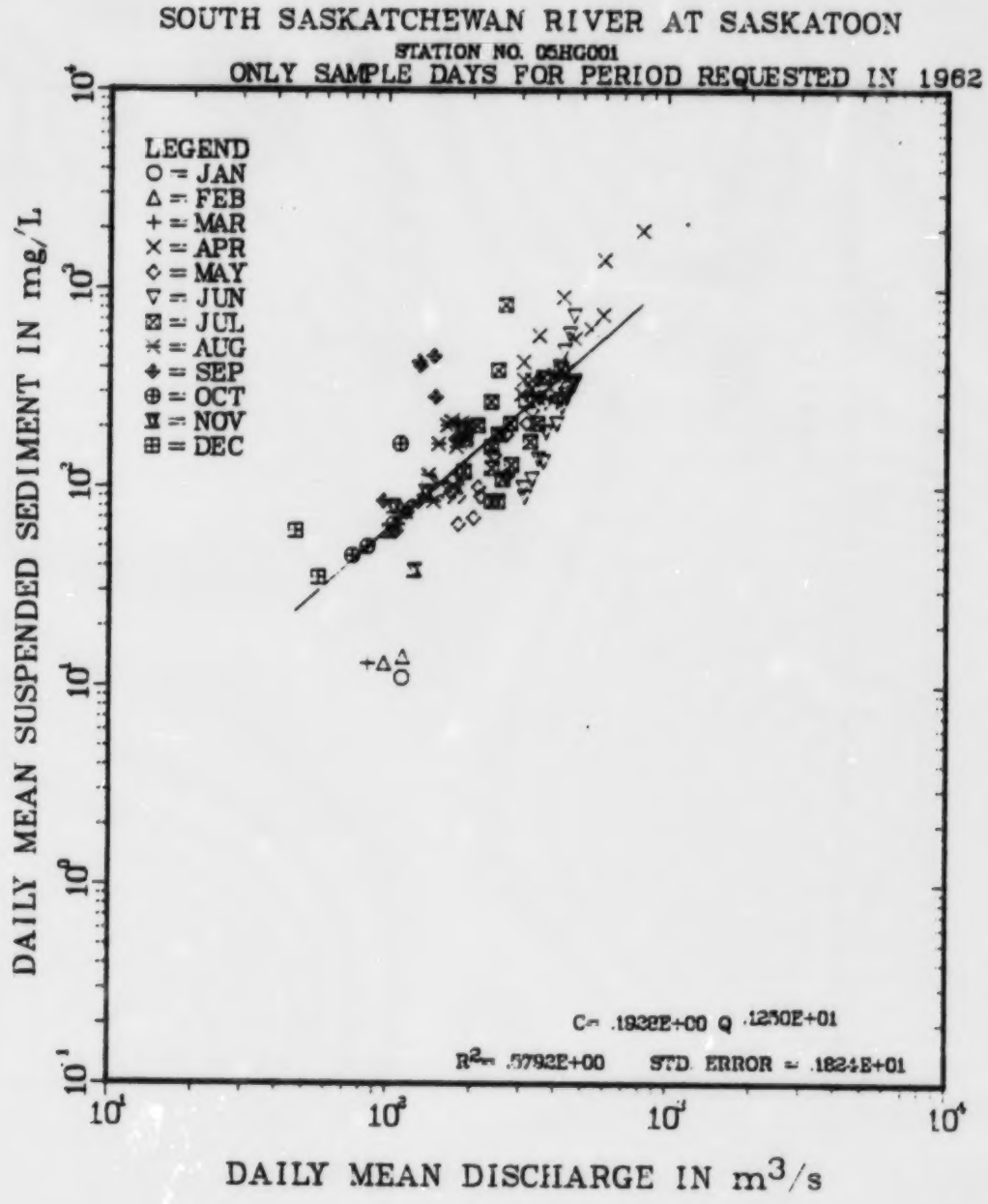

SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLE DAYS FOR PERIOD REQUESTED
LEGEND
□ = 1961
○ = 1962
△ = 1963
+ = 1964
× = 1965
◇ = 1966
▽ = 1967
⊠ = 1968
✳ = 1969
◆ = 1970
⊕ = 1971
⧗ = 1975
C= .3391E-01 Q .1389E+01
R2= .6112E+00 STD. ERROR = .2545E+01
DAILY MEAN SUSPENDED SEDIMENT IN mg/L
DAILY MEAN DISCHARGE IN m3/s

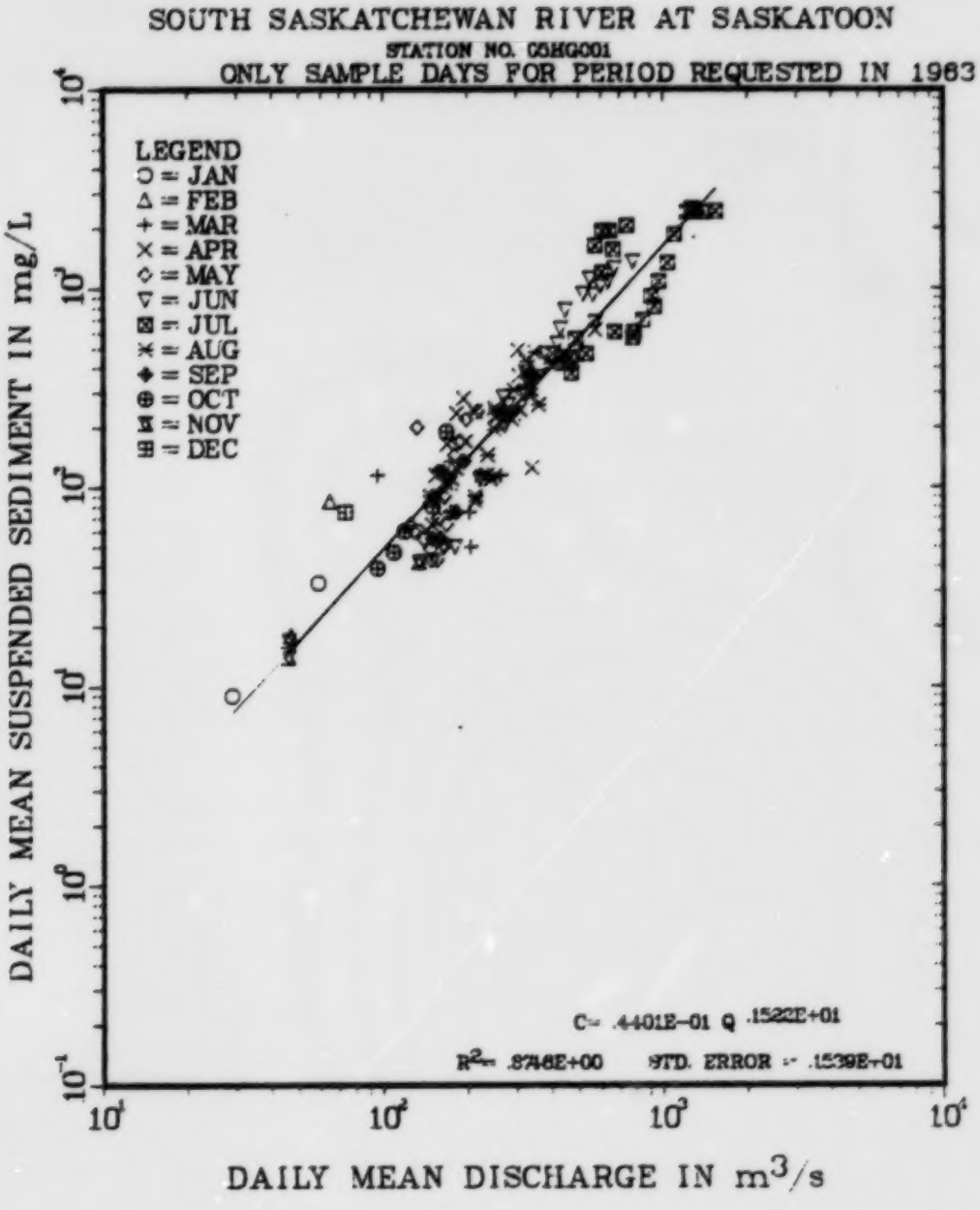
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1961



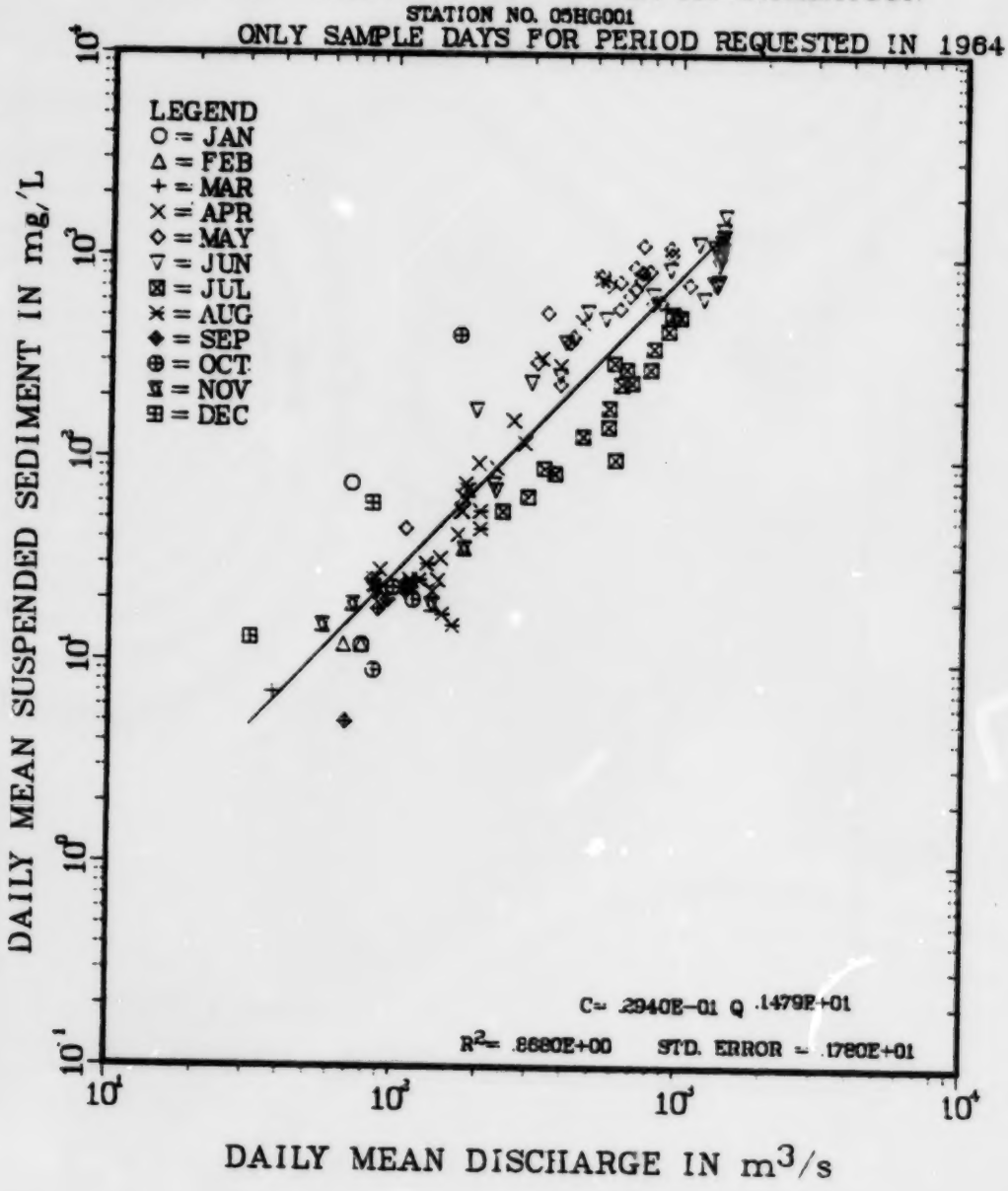

SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1962
LEGEND
○ = JAN
△ = FEB
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✳ = AUG
◆ = SEP
⊕ = OCT
⧗ = NOV
⊞ = DEC
C= .1932E+00 Q .1250E+01
R2= .5792E+00 STD. ERROR = .1824E+01
DAILY MEAN SUSPENDED SEDIMENT IN mg/L
DAILY MEAN DISCHARGE IN m3/s


SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1963
LEGEND
○ = JAN
△ = FEB
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✳ = AUG
◆ = SEP
⊕ = OCT
⧗ = NOV
⊞ = DEC
C= .4401E-01 Q .1522E+01
R2= .8746E+00 STD. ERROR = .1539E+01
DAILY MEAN SUSPENDED SEDIMENT IN mg/L
DAILY MEAN DISCHARGE IN m3/s

SOUTH SASKATCHEWAN RIVER AT SASKATOON

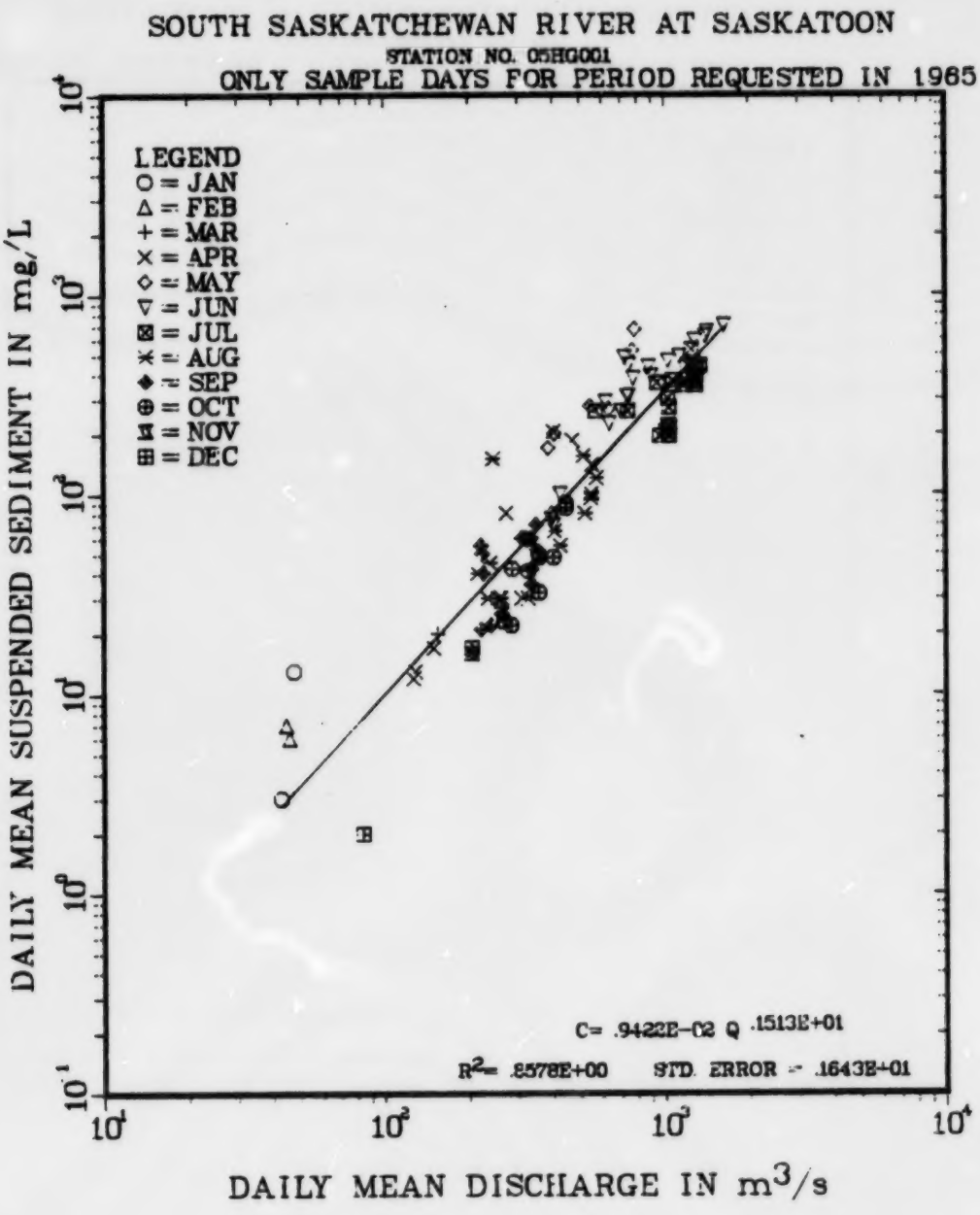
STATION NO. 05HG001

ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1964



DAILY MEAN SUSPENDED SEDIMENT IN mg/L

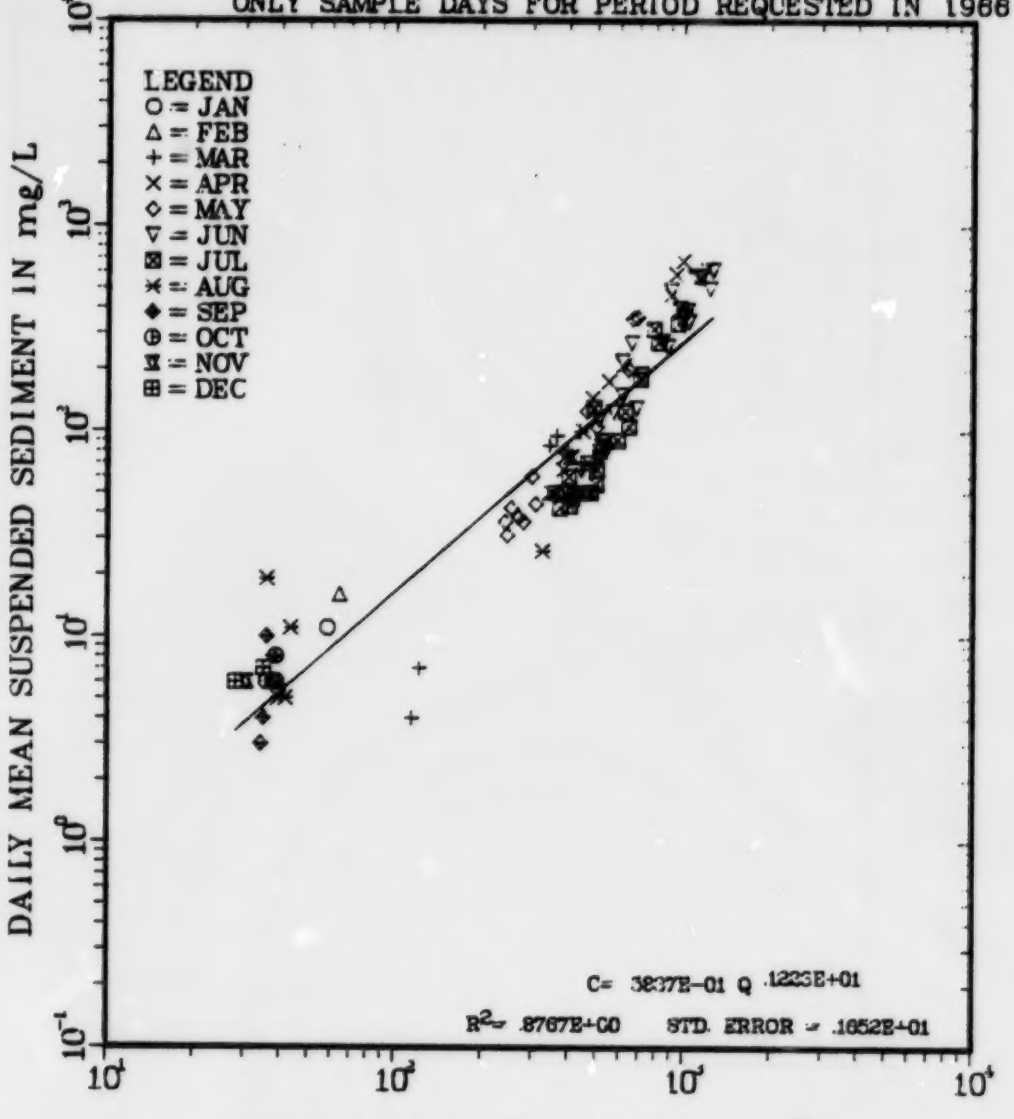
DAILY MEAN DISCHARGE IN m^3/s


SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1965
LEGEND
○ = JAN
△ = FEB
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✳ = AUG
◆ = SEP
⊕ = OCT
⧓ = NOV
⊞ = DEC
C= .9422E-02 Q .1513E+01
R2= .8578E+00 STD. ERROR = .1643E+01
DAILY MEAN SUSPENDED SEDIMENT IN mg/L
DAILY MEAN DISCHARGE IN m3/s
10-1
10⁰
10¹
10²
10³
10⁴

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1966



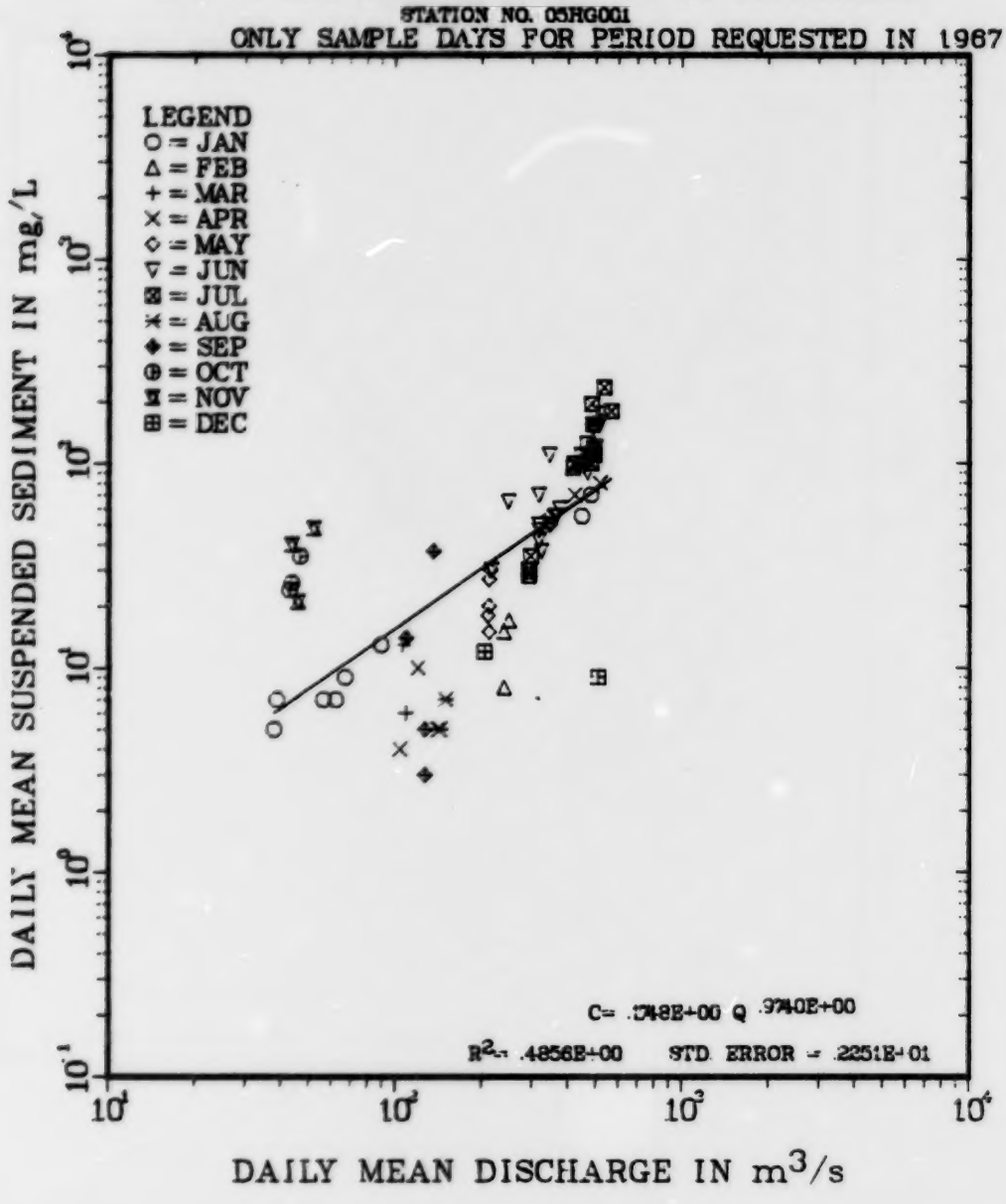
DAILY MEAN SUSPENDED SEDIMENT IN mg/L

DAILY MEAN DISCHARGE IN m^3/s

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

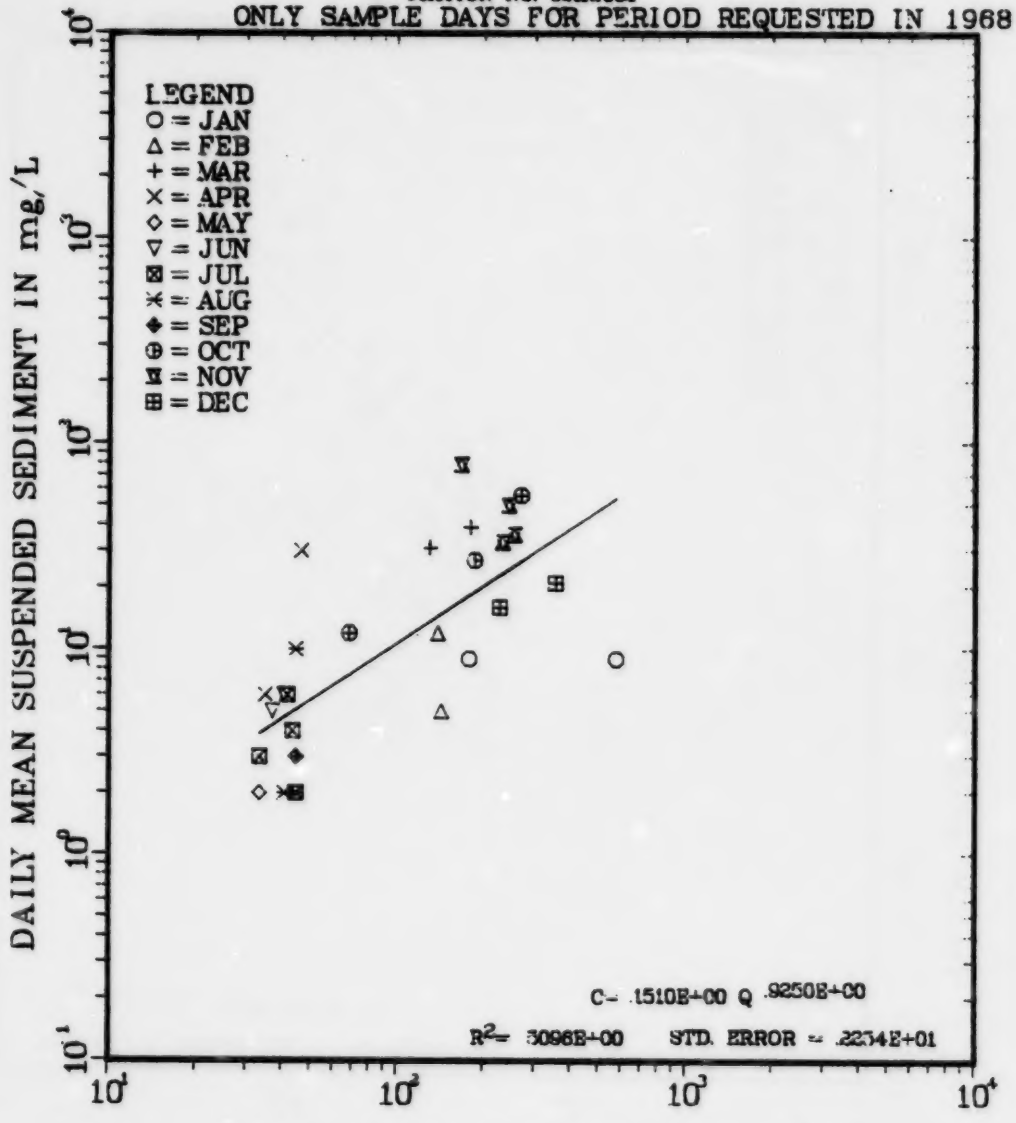
ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1967

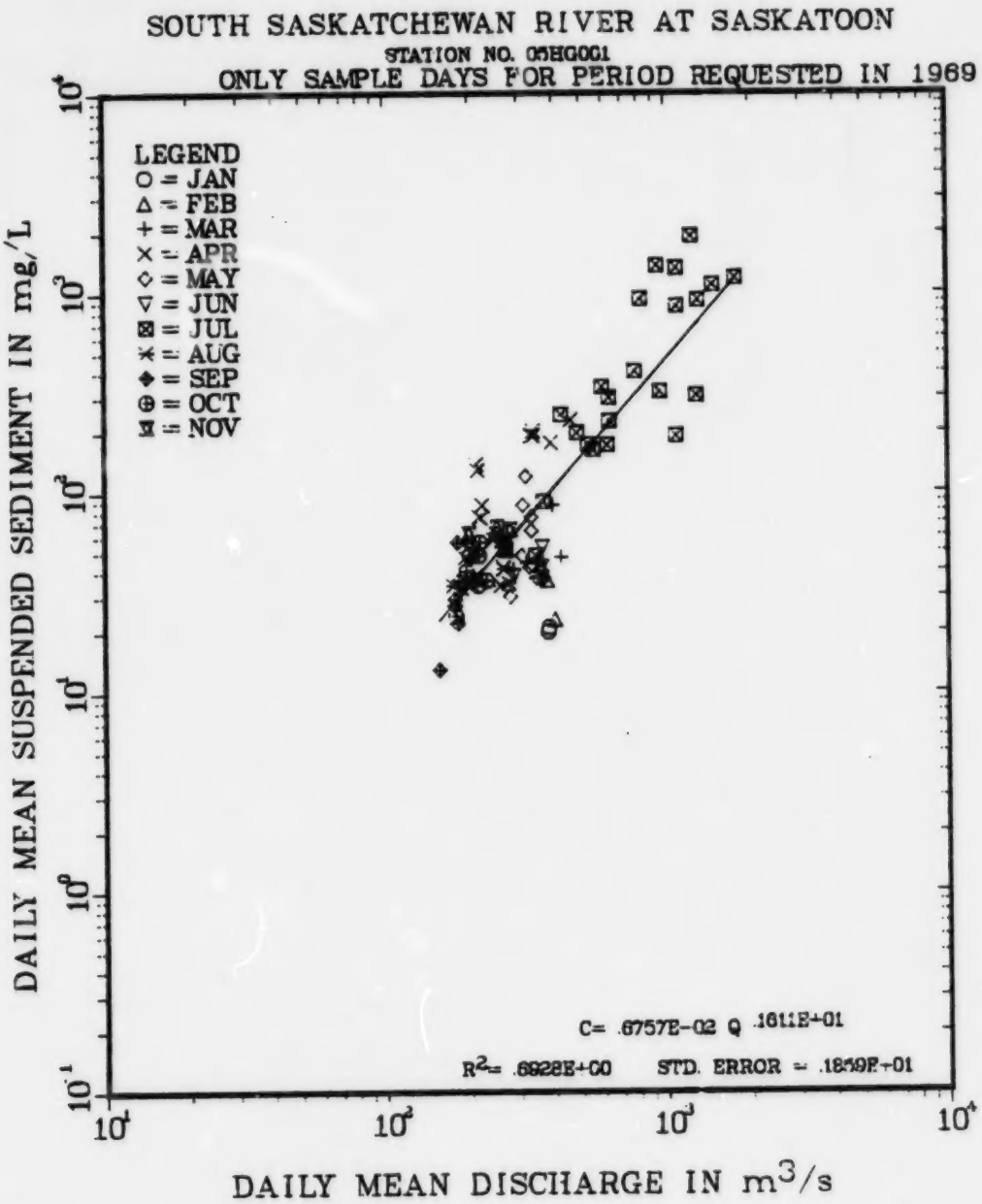


SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1968

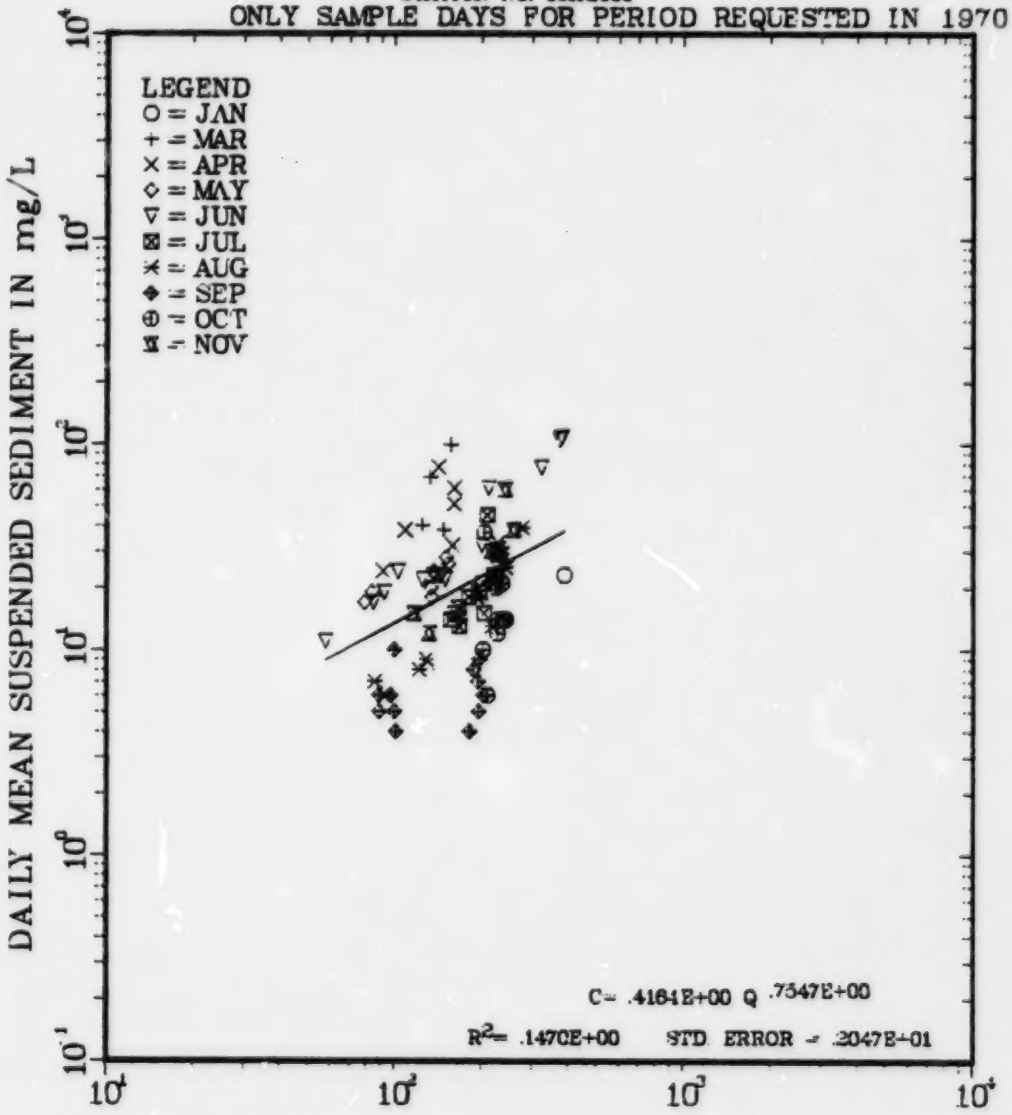



SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1969
LEGEND
○ = JAN
△ = FEB
+ = MAR
× = APR
◇ = MAY
▽ = JUN
⊠ = JUL
✳ = AUG
◆ = SEP
⊕ = OCT
▣ = NOV
C= .6757E-02 Q .1611E+01
R2= .6928E+00 STD. ERROR = .1859E+01
DAILY MEAN SUSPENDED SEDIMENT IN mg/L
DAILY MEAN DISCHARGE IN m3/s

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

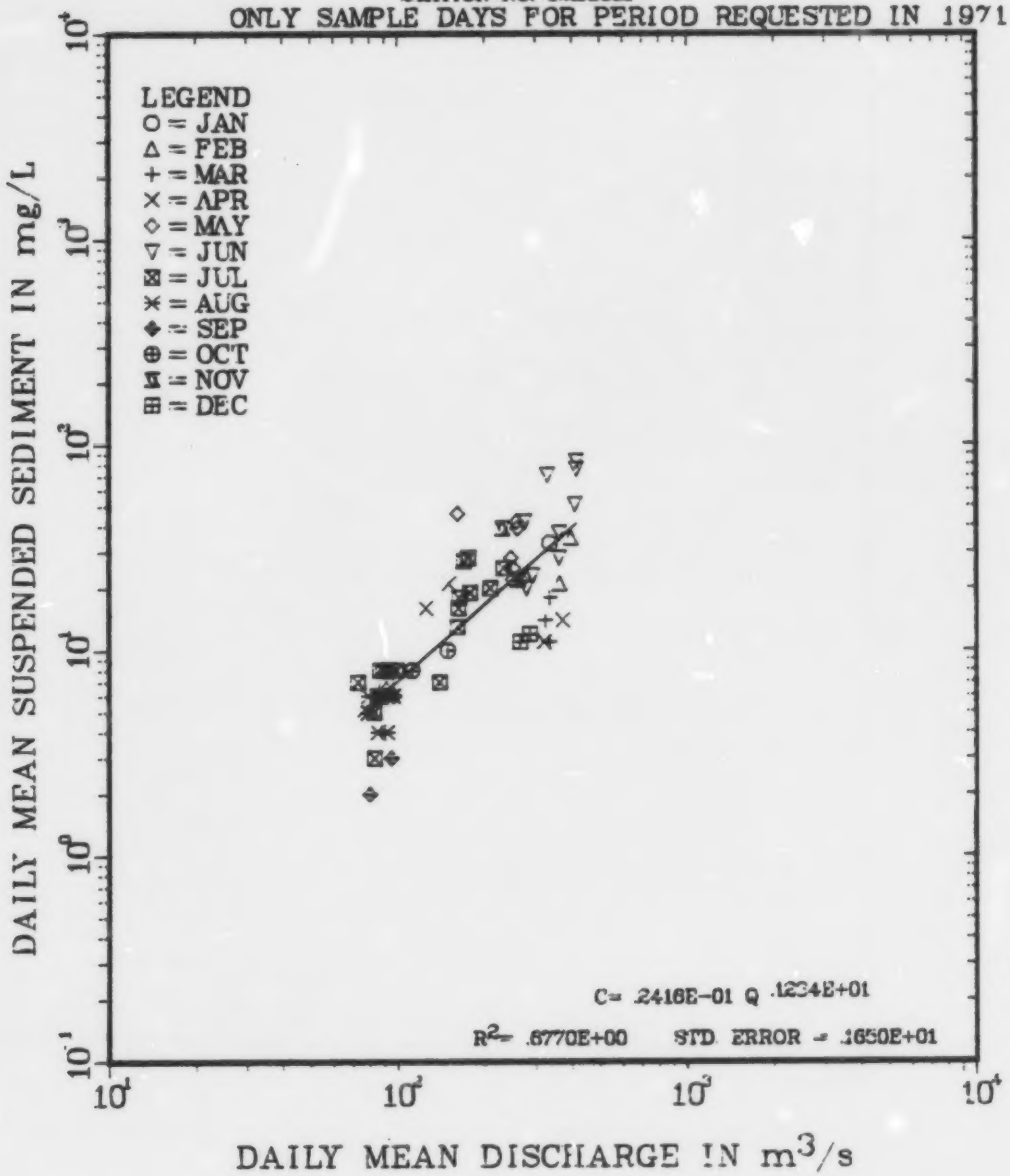
ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1970



SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1971



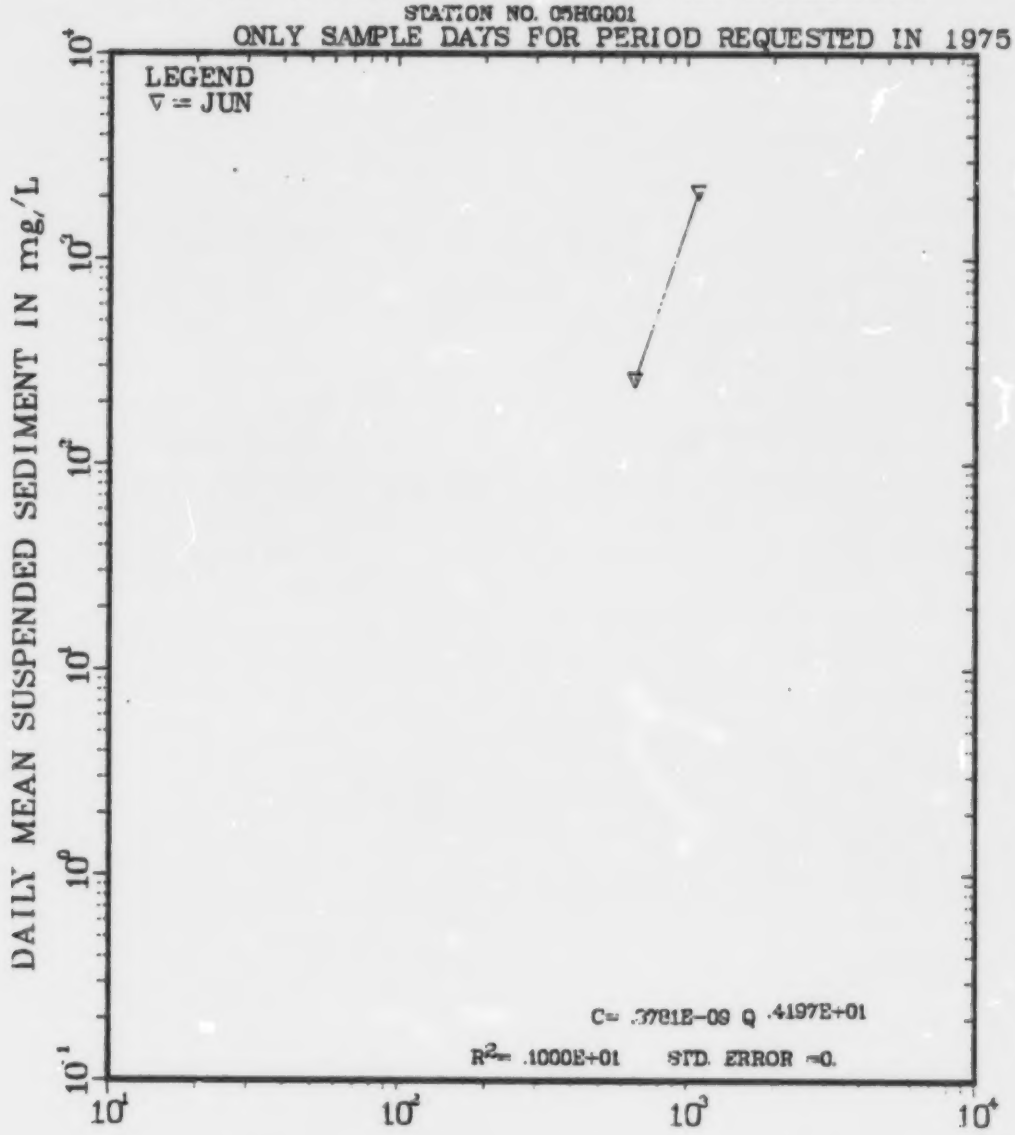
DAILY MEAN SUSPENDED SEDIMENT IN mg/L

DAILY MEAN DISCHARGE IN m^3/s

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

ONLY SAMPLE DAYS FOR PERIOD REQUESTED IN 1975



DAILY MEAN SUSPENDED SEDIMENT IN mg/L

DAILY MEAN DISCHARGE IN m^3/s

F

POINT INTEGRATING SEDIMENT DATA AND PLOTS

WATER SURVEY OF CANADA
07/08/88 , PAGE 1
SEDIMENT SURVEY SECTION

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
JUN 20 1963		671	36.6	.15	980	167 (17%)	715 (73%)	882 (90%)	98 (10%)
				1.40	1 070	193 (18%)	728 (68%)	920 (86%)	150 (14%)
				2.26	1 150	150 (13%)	759 (66%)	909 (79%)	242 (21%)
				2.59	1 160	174 (15%)	789 (68%)	963 (83%)	197 (17%)
				2.80	STREAMBED				
				MIN	980	150	715	882	98
				MAX	1 160	193	789	963	242
				DIFF(%)	16	22	9	8	59
				MEAN	1 090	171	748	918	172
			67.1	.15	1 160	174 (15%)	800 (69%)	974 (84%)	186 (16%)
				1.46	1 160	139 (12%)	766 (66%)	905 (78%)	255 (22%)
				2.35	1 600	320 (20%)	800 (50%)	1 120 (70%)	480 (30%)
				2.71	1 910	229 (12%)	764 (40%)	993 (52%)	917 (48%)
				2.93	STREAMBED				
				MIN	1 160	139	764	905	186
				MAX	1 910	320	800	1 120	917
				DIFF(%)	39	56	5	19	80
				MEAN	1 458	216	782	998	459
			103.6	.15	920	184 (20%)	672 (73%)	856 (93%)	64 (7%)
				1.01	1 150	265 (23%)	725 (63%)	989 (86%)	161 (14%)
				2.04	1 320	290 (22%)	779 (59%)	1 069 (81%)	251 (19%)
				2.71	1 390	264 (19%)	792 (57%)	1 056 (76%)	334 (24%)
				3.17	1 700	323 (19%)	799 (47%)	1 122 (66%)	578 (34%)
				3.38	STREAMBED				
				MIN	920	184	672	856	64
				MAX	1 700	323	799	1 122	578
				DIFF(%)	46	43	16	24	89
				MEAN	1 296	265	753	1 018	278
			131.1	.15	1 080	270 (25%)	713 (66%)	983 (91%)	97 (9%)
				1.25	1 280	128 (10%)	794 (62%)	922 (72%)	358 (28%)
				2.53	1 570	298 (19%)	801 (51%)	1 099 (70%)	471 (30%)
				3.35	1 660	315 (19%)	797 (48%)	1 112 (67%)	548 (33%)
				4.21	STREAMBED				
				MIN	1 080	128	713	922	97
				MAX	1 660	315	801	1 112	548
				DIFF(%)	35	59	11	17	82
				MEAN	1 398	253	776	1 029	369

WATER SURVEY OF CANADA
07/09/88 PAGE 2
SEDIMENT SURVEY SECTION

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
JUN 20 1963		671	161.5	.15	1 030	278 (27%)	690 (67%)	968 (94%)	62 (6%)
				.98	1 150	265 (23%)	759 (66%)	1 024 (89%)	127 (11%)
				1.95	1 300	286 (22%)	767 (59%)	1 053 (81%)	247 (19%)
				2.59	1 340	161 (12%)	777 (58%)	938 (70%)	402 (30%)
				3.02	1 500	210 (14%)	735 (49%)	945 (63%)	555 (37%)
				3.23	STREAMBED				
				MIN	1 030	161	690	938	62
				MAX	1 500	286	777	1 053	555
				DIFF(%)	31	44	11	11	89
				MEAN	1 264	240	746	986	278
			MIN	.15	920	128	672	856	62
			MAX	4.21	1 910	323	801	1 122	917
			DIFF(%)		52	60	16	24	93
			MEAN		1 299	231	760	991	308

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
MAY 12 1964	16:00	527	56.6	1.22	600	6 (1%)	462 (77%)	468 (78%)	132 (22%)
				1.98	655	52 (8%)	439 (67%)	491 (75%)	164 (25%)
				2.16	690	35 (5%)	476 (69%)	511 (74%)	179 (26%)
				2.47	STREAMBED				
				MIN	600	6	439	468	132
				MAX	690	52	476	511	179
				DIFF(%)	13	89	8	8	26
				MEAN	648	31	459	490	158
			67.1	.30	660	53 (8%)	469 (71%)	521 (79%)	139 (21%)
				1.28	790	16 (2%)	506 (64%)	521 (66%)	269 (34%)
				2.07	1 000	50 (5%)	540 (54%)	590 (59%)	410 (41%)
				2.29	1 050	84 (8%)	515 (49%)	599 (57%)	452 (43%)
				2.59	STREAMBED				
				MIN	660	16	469	521	139
				MAX	1 050	84	540	599	452
				DIFF(%)	37	81	13	13	69
				MEAN	875	51	507	558	317
			103.6	.30	585	12 (2%)	369 (63%)	380 (65%)	205 (35%)
				1.01	760	46 (6%)	433 (57%)	479 (63%)	281 (37%)
				2.01	965	48 (5%)	405 (42%)	454 (47%)	511 (53%)
				2.68	1 110	56 (5%)	455 (41%)	511 (46%)	599 (54%)
				3.05	1 260	50 (4%)	517 (41%)	567 (45%)	693 (55%)
				3.35	STREAMBED				
				MIN	585	12	369	380	205
				MAX	1 260	56	517	567	693
				DIFF(%)	54	79	29	33	70
				MEAN	936	42	436	478	458
			131.1	.30	490	10 (2%)	338 (69%)	348 (71%)	142 (29%)
				1.16	725	22 (3%)	355 (49%)	377 (52%)	348 (48%)
				2.32	865	26 (3%)	355 (41%)	381 (44%)	484 (56%)
				3.08	1 260	38 (3%)	416 (33%)	454 (36%)	806 (64%)
				3.54	1 890	76 (4%)	454 (24%)	529 (28%)	1 361 (72%)
				3.84	STREAMBED				
				MIN	490	10	338	348	142
				MAX	1 890	76	454	529	1 361
				DIFF(%)	74	87	25	34	90
				MEAN	1 046	34	383	418	628

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
MAY 12 1964	16:00	527	161.5	.30	565	51 (9%)	412 (73%)	463 (82%)	102 (18%)
				.98	620	19 (3%)	434 (70%)	453 (73%)	167 (27%)
				1.89	775	62 (8%)	473 (61%)	535 (69%)	240 (31%)
				2.53	850	60 (7%)	476 (56%)	536 (63%)	315 (37%)
				2.87	1 030	72 (7%)	505 (49%)	577 (56%)	453 (44%)
				3.17	STREAMBED				
				MIN	565	19	412	453	102
				MAX	1 030	72	505	577	453
				DIFF(%)	45	74	18	22	78
				MEAN	768	53	460	513	255
			192.0	.30	720	94 (13%)	518 (72%)	612 (85%)	108 (15%)
				.76	725	65 (9%)	522 (72%)	587 (81%)	138 (19%)
				1.22	815	82 (10%)	562 (69%)	644 (79%)	171 (21%)
				1.43	1 000	50 (5%)	630 (63%)	680 (68%)	320 (32%)
				1.52	STREAMBED				
				MIN	720	50	518	587	108
				MAX	1 000	94	630	680	320
				DIFF(%)	28	47	18	14	66
				MEAN	815	73	558	631	184
			MIN	.30	490	6	338	348	102
			MAX	3.84	1 890	94	630	680	1 361
			DIFF(%)		74	94	46	49	93
			MEAN		864	47	463	510	353

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
MAY 20 1964	16:30	677	36.6	1.43	455	114 (25%)	300 (66%)	414 (91%)	41 (9%)
				2.29	560	129 (23%)	347 (62%)	476 (85%)	84 (15%)
				2.56	580	226 (39%)	261 (45%)	487 (84%)	93 (16%)
				2.90	STREAMBED				
				MIN	455	114	261	414	41
				MAX	580	226	347	487	93
				DIFF(%)	22	50	25	15	56
				MEAN	532	156	303	459	73
			67.1	.30	550	193 (35%)	264 (48%)	457 (83%)	94 (17%)
				1.40	705	240 (34%)	254 (36%)	494 (70%)	212 (30%)
				2.26	825	256 (31%)	264 (32%)	520 (63%)	305 (37%)
				2.50	1 020	204 (20%)	275 (27%)	479 (47%)	541 (53%)
				2.80	STREAMBED				
				MIN	550	193	254	457	94
				MAX	1 020	256	275	520	541
				DIFF(%)	46	25	8	12	83
				MEAN	775	223	264	487	288
			103.6	.30	550	237 (43%)	242 (44%)	479 (87%)	72 (13%)
				1.10	680	292 (43%)	218 (32%)	510 (75%)	170 (25%)
				2.23	720	230 (32%)	259 (36%)	490 (68%)	230 (32%)
				2.96	1 040	281 (27%)	239 (23%)	520 (50%)	520 (50%)
				3.38	1 140	194 (17%)	262 (23%)	456 (40%)	684 (60%)
				3.47	STREAMBED				
				MIN	550	194	218	456	72
				MAX	1 140	292	262	520	684
				DIFF(%)	52	34	17	12	90
				MEAN	826	247	244	491	335
			131.1	.30	490	191 (39%)	221 (45%)	412 (84%)	78 (16%)
				1.22	465	172 (37%)	214 (46%)	386 (83%)	79 (17%)
				2.41	550	160 (29%)	242 (44%)	402 (73%)	149 (27%)
				3.23	735	184 (25%)	228 (31%)	412 (56%)	323 (44%)
				3.72	1 300	221 (17%)	195 (15%)	416 (32%)	884 (68%)
				3.84	STREAMBED				
				MIN	465	160	195	386	78
				MAX	1 300	221	242	416	884
				DIFF(%)	64	28	19	7	91
				MEAN	708	185	220	405	303

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
MAY 20 1964	16:30	677	161.5	.30	380	141 (37%)	209 (55%)	350 (92%)	30 (8%)
				.88	510	230 (45%)	189 (37%)	418 (82%)	92 (18%)
				1.95	730	226 (31%)	212 (29%)	438 (60%)	292 (40%)
				2.62	1 110	289 (26%)	211 (19%)	500 (45%)	611 (55%)
				2.83	1 270	178 (14%)	216 (17%)	394 (31%)	876 (69%)
				2.93	STREAMBED				
				MIN	380	141	189	350	30
				MAX	1 270	289	216	500	876
				DIFF(%)	70	51	13	30	97
				MEAN	800	213	207	420	380
			192.0	.30	425	208 (49%)	187 (44%)	395 (93%)	30 (7%)
				.91	535	257 (48%)	219 (41%)	476 (89%)	59 (11%)
				1.49	535	257 (48%)	203 (38%)	460 (86%)	75 (14%)
				1.55	625	300 (48%)	188 (30%)	488 (78%)	138 (22%)
				1.65	STREAMBED				
				MIN	425	208	187	395	30
				MAX	625	300	219	488	138
				DIFF(%)	32	31	15	19	78
				MEAN	530	255	199	455	75
			MIN	.30	380	114	187	350	30
			MAX	3.84	1 300	300	347	520	884
			DIFF(%)		71	62	46	33	97
			MEAN		711	216	235	451	260

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
MAY 10 1965	17:00	753	51.8	.09	305	73 (24%)	116 (38%)	189 (62%)	116 (38%)
				1.34	595	71 (12%)	143 (24%)	214 (36%)	381 (64%)
				2.13	750	90 (12%)	143 (19%)	233 (31%)	518 (69%)
				2.53	935	75 (8%)	150 (16%)	224 (24%)	711 (76%)
				2.65	STREAMBED				
				MIN	305	71	116	189	116
				MAX	935	90	150	233	711
				DIFF(%)	67	21	23	19	84
				MEAN	646	77	138	215	431
			103.6	.09	320	54 (17%)	122 (38%)	176 (55%)	144 (45%)
				1.25	465	37 (8%)	130 (28%)	167 (36%)	298 (64%)
				2.01	735	66 (9%)	132 (18%)	198 (27%)	537 (73%)
				2.38	910	64 (7%)	137 (15%)	200 (22%)	710 (78%)
				2.50	STREAMBED				
				MIN	320	37	122	167	144
				MAX	910	66	137	200	710
				DIFF(%)	65	44	11	16	80
				MEAN	608	55	130	186	422
			155.4	.09	255	66 (26%)	97 (38%)	163 (64%)	92 (36%)
				1.34	400	48 (12%)	124 (31%)	172 (43%)	228 (57%)
				2.13	650	91 (14%)	117 (18%)	208 (32%)	442 (68%)
				2.53	880	79 (9%)	132 (15%)	211 (24%)	669 (76%)
				2.65	STREAMBED				
				MIN	255	48	97	163	92
				MAX	880	91	132	211	669
				DIFF(%)	71	47	27	23	86
				MEAN	546	71	117	189	358
			207.3	.09	355	114 (32%)	117 (33%)	231 (65%)	124 (35%)
				1.28	510	112 (22%)	117 (23%)	230 (45%)	281 (55%)
				2.07	705	92 (13%)	148 (21%)	240 (34%)	465 (66%)
				2.47	1 240	87 (7%)	136 (11%)	223 (18%)	1 017 (82%)
				2.59	STREAMBED				
				MIN	355	87	117	223	124
				MAX	1 240	114	148	240	1 017
				DIFF(%)	71	24	21	7	88
				MEAN	703	101	130	231	472

WATER SURVEY OF CANADA
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SEDIMENT SURVEY SECTION

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
MAY 10 1965	17:00	753	259.1	.09	275	113 (41%)	110 (40%)	223 (81%)	52 (19%)
				1.46	415	91 (22%)	141 (34%)	232 (56%)	183 (44%)
				2.38	605	54 (9%)	151 (25%)	206 (34%)	399 (66%)
				2.83	680	68 (10%)	156 (23%)	224 (33%)	456 (67%)
				2.96	STREAMBED				
				MIN	275	54	110	206	52
				MAX	680	113	156	232	456
				DIFF(%)	60	52	30	11	89
				MEAN	494	82	140	221	272
			MIN	.09	255	37	97	163	52
			MAX	2.96	1 240	114	156	240	1 017
			DIFF(%)		79	67	38	32	95
			MEAN		599	77	131	208	391

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
JUN 25 1965	14:00	1 280	51.8	.91	650	46 (7%)	221 (34%)	267 (41%)	384 (59%)
				1.83	905	63 (7%)	235 (26%)	299 (33%)	606 (67%)
				2.47	880	53 (6%)	211 (24%)	264 (30%)	616 (70%)
				3.02	1 700	68 (4%)	238 (14%)	306 (18%)	1 394 (82%)
				3.08	STREAMBED				
				MIN	650	46	211	264	384
				MAX	1 700	68	238	306	1 394
				DIFF(%)	62	33	11	14	72
				MEAN	1 034	57	226	284	750
			103.6	.09	320	58 (18%)	173 (54%)	230 (72%)	90 (28%)
				.98	470	47 (10%)	207 (44%)	254 (54%)	216 (46%)
				1.98	520	31 (6%)	208 (40%)	239 (46%)	281 (54%)
				2.62	820	66 (8%)	213 (26%)	279 (34%)	541 (66%)
				3.23	1 520	46 (3%)	228 (15%)	274 (18%)	1 246 (82%)
				3.38	STREAMBED				
				MIN	320	31	173	230	90
				MAX	1 520	66	228	279	1 246
				DIFF(%)	79	52	24	17	93
				MEAN	730	49	206	255	475
			155.4	1.07	575	58 (10%)	265 (46%)	322 (56%)	253 (44%)
				2.13	735	51 (7%)	184 (25%)	235 (32%)	500 (68%)
				2.63	990	30 (3%)	218 (22%)	248 (25%)	743 (75%)
				3.47	2 060			248 (25%)	1 813 (88%)
				3.54	STREAMBED				
				MIN	575	30	184	235	253
				MAX	2 060	58	265	322	1 813
				DIFF(%)	72	48	31	27	86
				MEAN	1 090	46	222	268	827
			207.3	.91	445	62 (14%)	200 (45%)	263 (59%)	182 (41%)
				1.86	635	76 (12%)	197 (31%)	273 (43%)	362 (57%)
				2.47	870	70 (8%)	226 (26%)	296 (34%)	574 (66%)
				3.02	1 710	51 (3%)	239 (14%)	291 (17%)	1 419 (83%)
				3.08	STREAMBED				
				MIN	445	51	197	263	182
				MAX	1 710	76	239	296	1 419
				DIFF(%)	74	33	18	11	87
				MEAN	915	65	216	281	634

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
JUN 25 1965	14:00	1 280	259.1	1.10	420	63 (15%)	176 (42%)	239 (57%)	181 (43%)
				2.23	675	47 (7%)	209 (31%)	257 (38%)	419 (62%)
				2.96	695	28 (4%)	222 (32%)	250 (36%)	445 (64%)
				3.63	1 320	53 (4%)	185 (14%)	238 (18%)	1 082 (82%)
				3.69	STREAMBED				
				MIN	420	28	176	238	181
				MAX	1 320	63	222	257	1 082
			DIFF(%)		68	56	21	7	83
			MEAN		778	48	198	246	532
			MIN	.09	320	28	173	230	90
			MAX	3.69	2 060	76	265	322	1 813
			DIFF(%)		84	64	35	28	95
			MEAN		901	53	213	266	636

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
APR 8 1966	14:00	912	51.8	.09	375	34 (9%)	131 (35%)	165 (44%)	210 (56%)
				1.52	735	44 (6%)	140 (19%)	184 (25%)	551 (75%)
				2.47	970	49 (5%)	146 (15%)	194 (20%)	776 (80%)
				2.71	1 110	56 (5%)	144 (13%)	200 (18%)	910 (82%)
				2.93	675	34 (5%)	142 (21%)	176 (26%)	500 (74%)
				3.02	STREAMBED				
				MIN	375	34	131	165	210
				MAX	1 110	56	146	200	910
				DIFF(%)	66	39	10	17	77
				MEAN	773	43	140	184	589
			103.6	.09	335	60 (18%)	104 (31%)	164 (49%)	171 (51%)
				1.40	475	38 (8%)	124 (26%)	162 (34%)	314 (66%)
				2.26	625	38 (6%)	125 (20%)	163 (26%)	463 (74%)
				2.53	685	55 (8%)	110 (16%)	164 (24%)	521 (76%)
				2.74	515	31 (6%)	124 (24%)	155 (30%)	361 (70%)
				2.83	STREAMBED				
				MIN	335	31	104	155	171
				MAX	685	60	125	164	521
				DIFF(%)	51	49	17	6	67
				MEAN	527	44	117	161	366
			155.4	.09	325	39 (12%)	133 (41%)	172 (53%)	153 (47%)
				1.37	485	34 (7%)	112 (23%)	146 (30%)	340 (70%)
				2.19	650	46 (7%)	111 (17%)	156 (24%)	494 (76%)
				2.44	725	44 (6%)	116 (16%)	160 (22%)	566 (78%)
				2.65	545	38 (7%)	120 (22%)	158 (29%)	387 (71%)
				2.74	STREAMBED				
				MIN	325	34	111	146	153
				MAX	725	46	133	172	566
				DIFF(%)	55	25	17	16	73
				MEAN	546	40	118	158	388
			207.3	.09	270	51 (19%)	95 (35%)	146 (54%)	124 (46%)
				1.46	575	40 (7%)	109 (19%)	150 (26%)	426 (74%)
				2.35	800	48 (6%)	144 (18%)	192 (24%)	608 (76%)
				2.62	680	44 (5%)	123 (14%)	167 (19%)	713 (81%)
				2.83	555	22 (4%)	128 (23%)	150 (27%)	405 (73%)
				2.93	STREAMBED				
				MIN	270	22	95	146	124
				MAX	880	51	144	192	713
				DIFF(%)	69	57	34	24	83
				MEAN	616	41	120	161	455

SOUTH SASKATCHEWAN RIVER AT SASKATOON

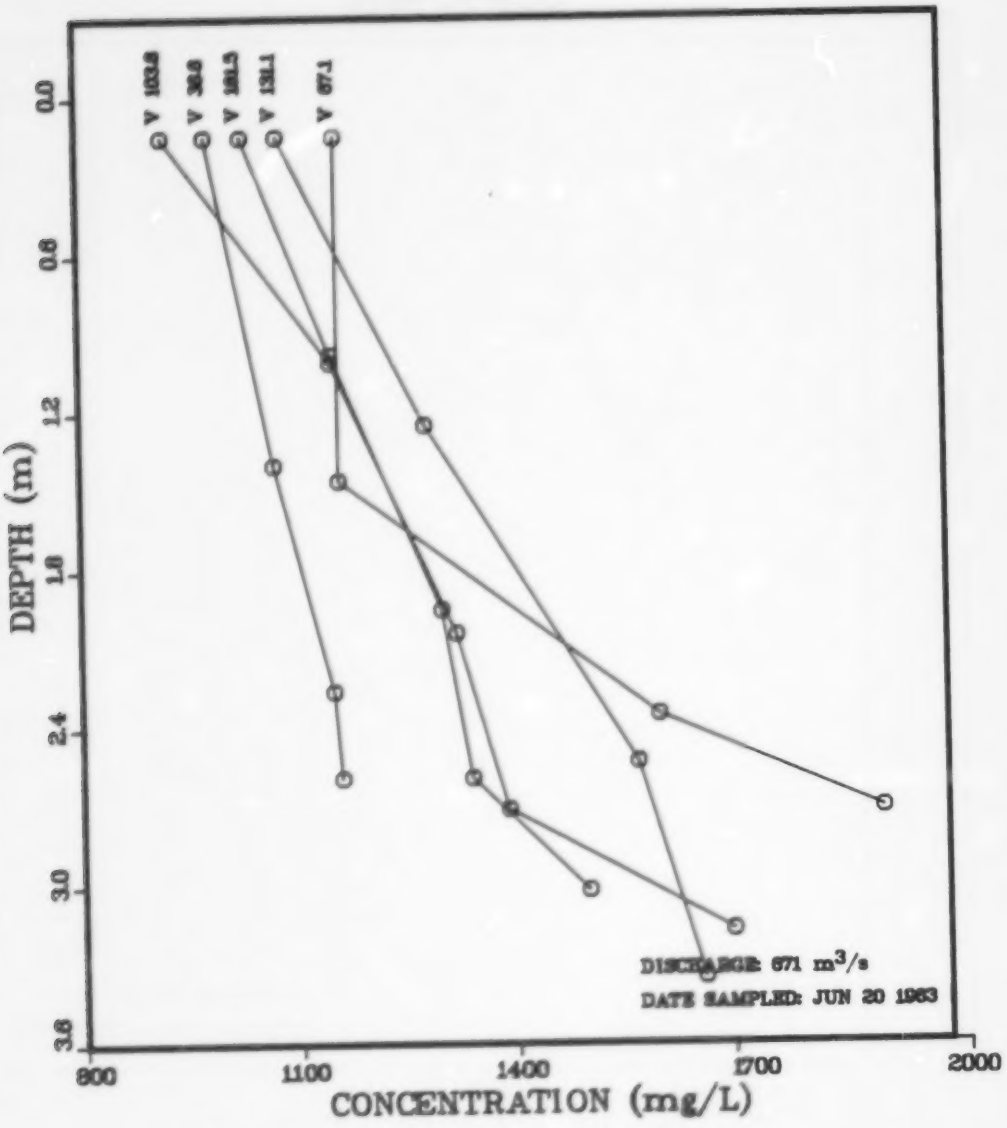
STATION NO. 05HG001

POINT INTEGRATING DATA

DATE SAMPLED	TIME	DISCHARGE	VERTICAL	DEPTH	CONCENTRATION	CLAY FRACTION	SILT FRACTION	SILT AND CLAY FRACTION	SAND FRACTION
APR 6 1966	14:00	912	259.1	.09	225	77 (34%)	92 (41%)	169 (75%)	56 (25%)
				1.40	480	43 (9%)	130 (27%)	173 (36%)	307 (64%)
				2.26	750	30 (4%)	135 (18%)	165 (22%)	585 (78%)
				2.44	550	28 (5%)	138 (25%)	165 (30%)	385 (70%)
				2.53	1 010	30 (3%)	121 (12%)	152 (15%)	859 (85%)
				2.83	STREAMBED				
				MIN	225	28	92	152	56
				MAX	1 010	77	138	173	859
				DIFF(%)	78	64	33	12	93
				MEAN	603	41	123	165	438
			MIN	.09	225	22	92	146	56
			MAX	3.02	1 110	77	146	200	910
			DIFF(%)		80	71	37	27	94
			MEAN		613	42	124	166	447

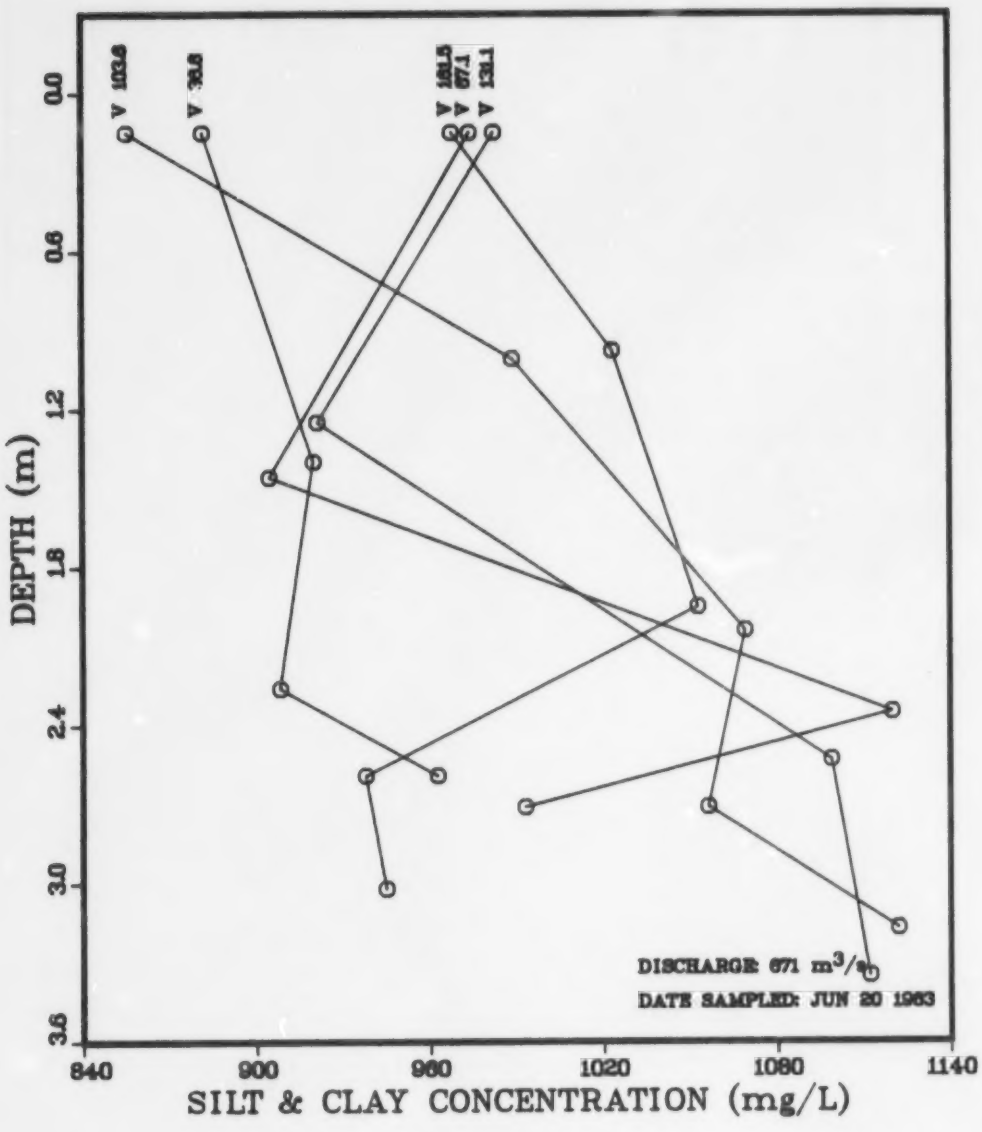
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05EG001



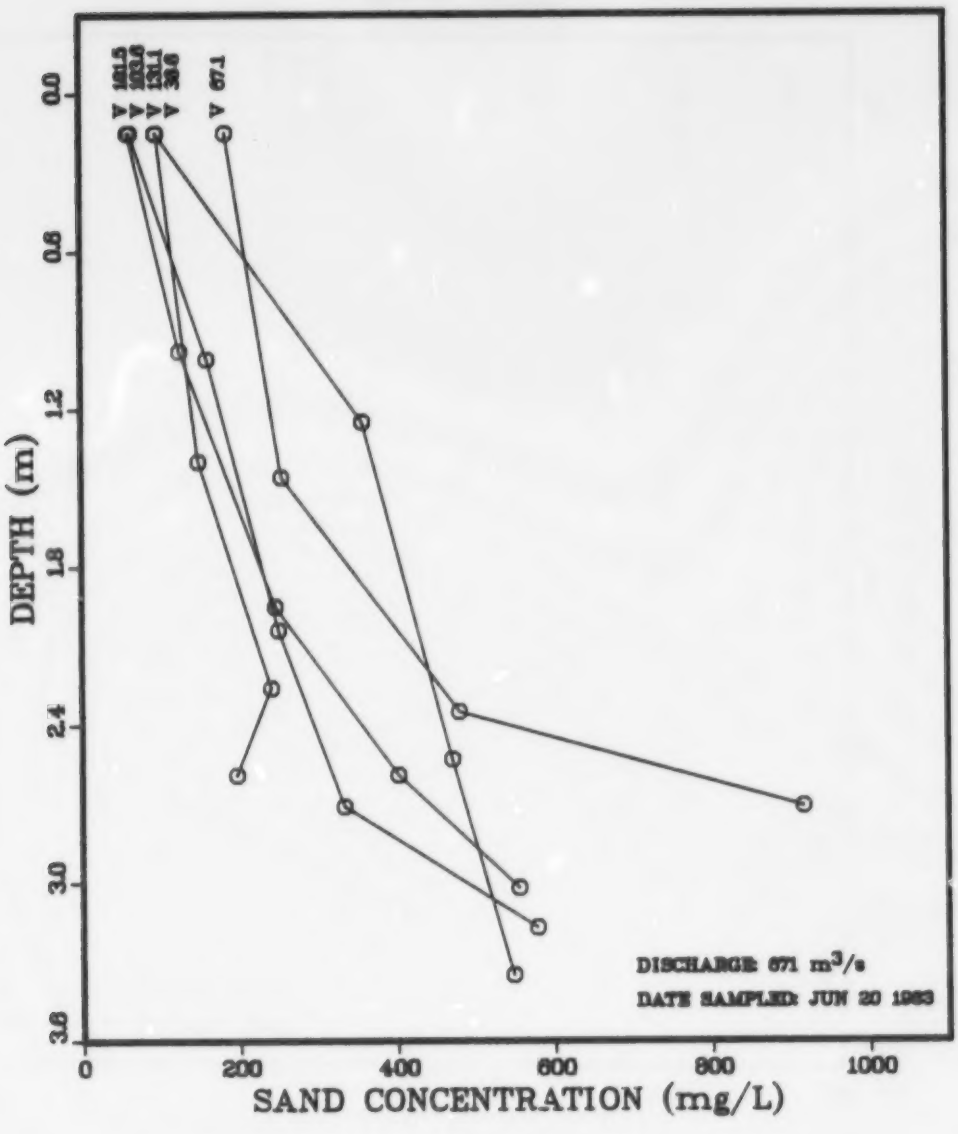
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



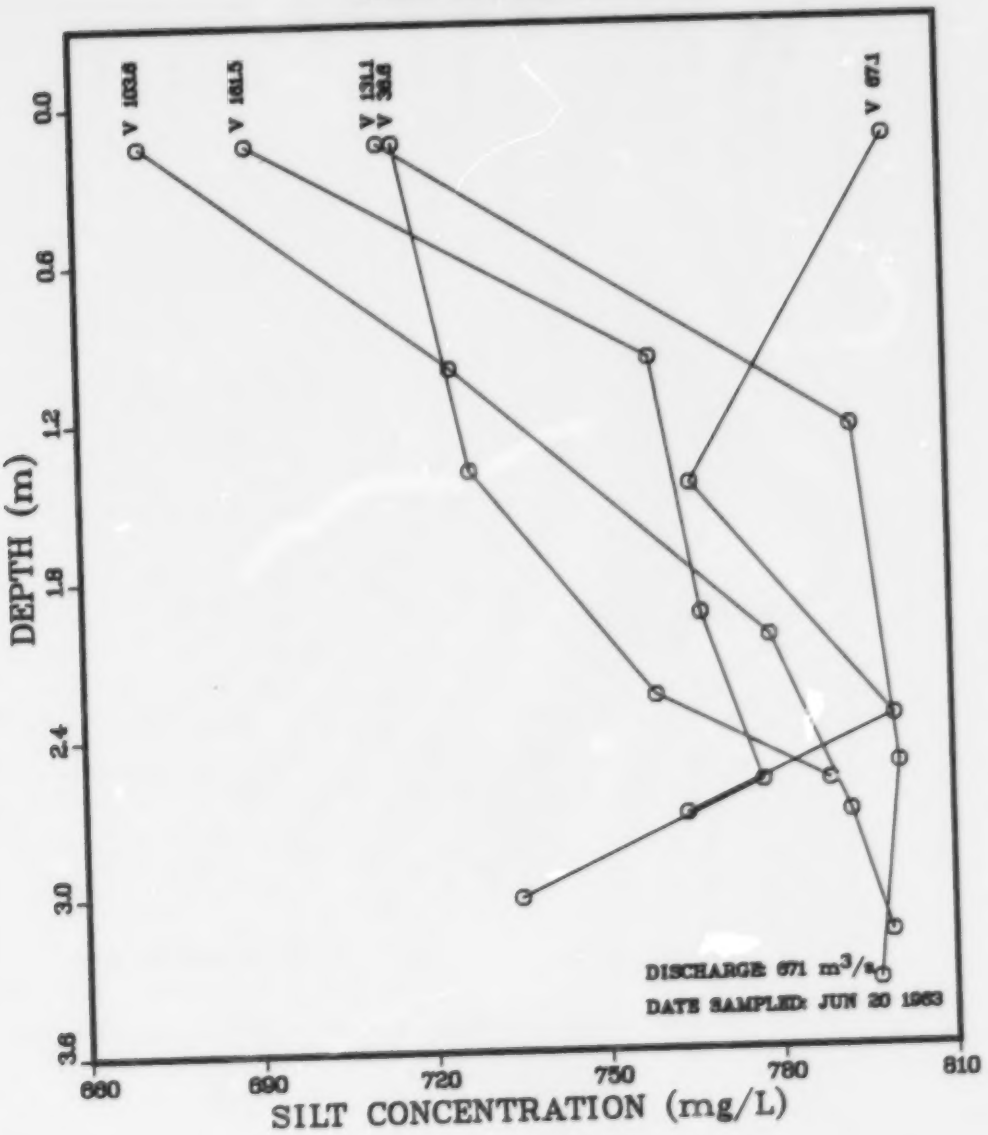
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



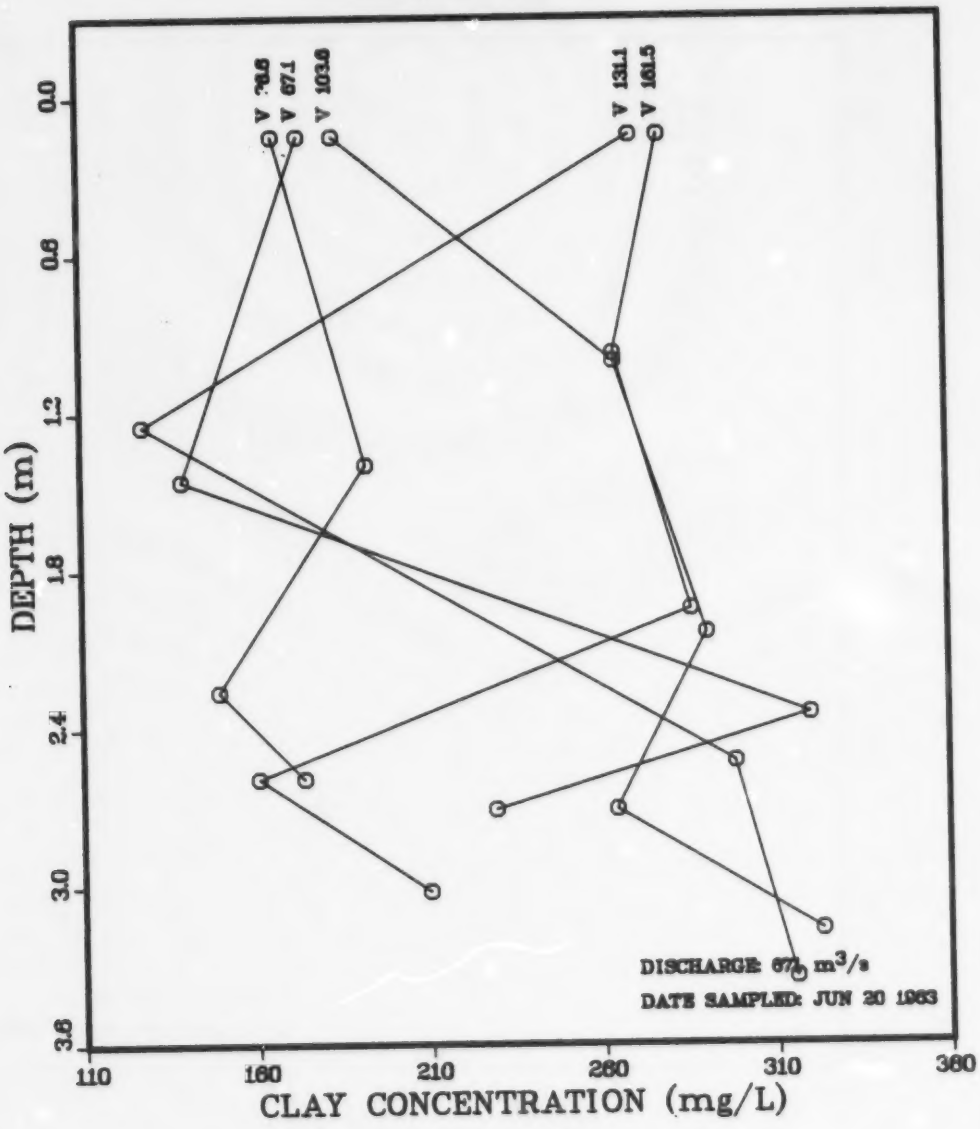
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



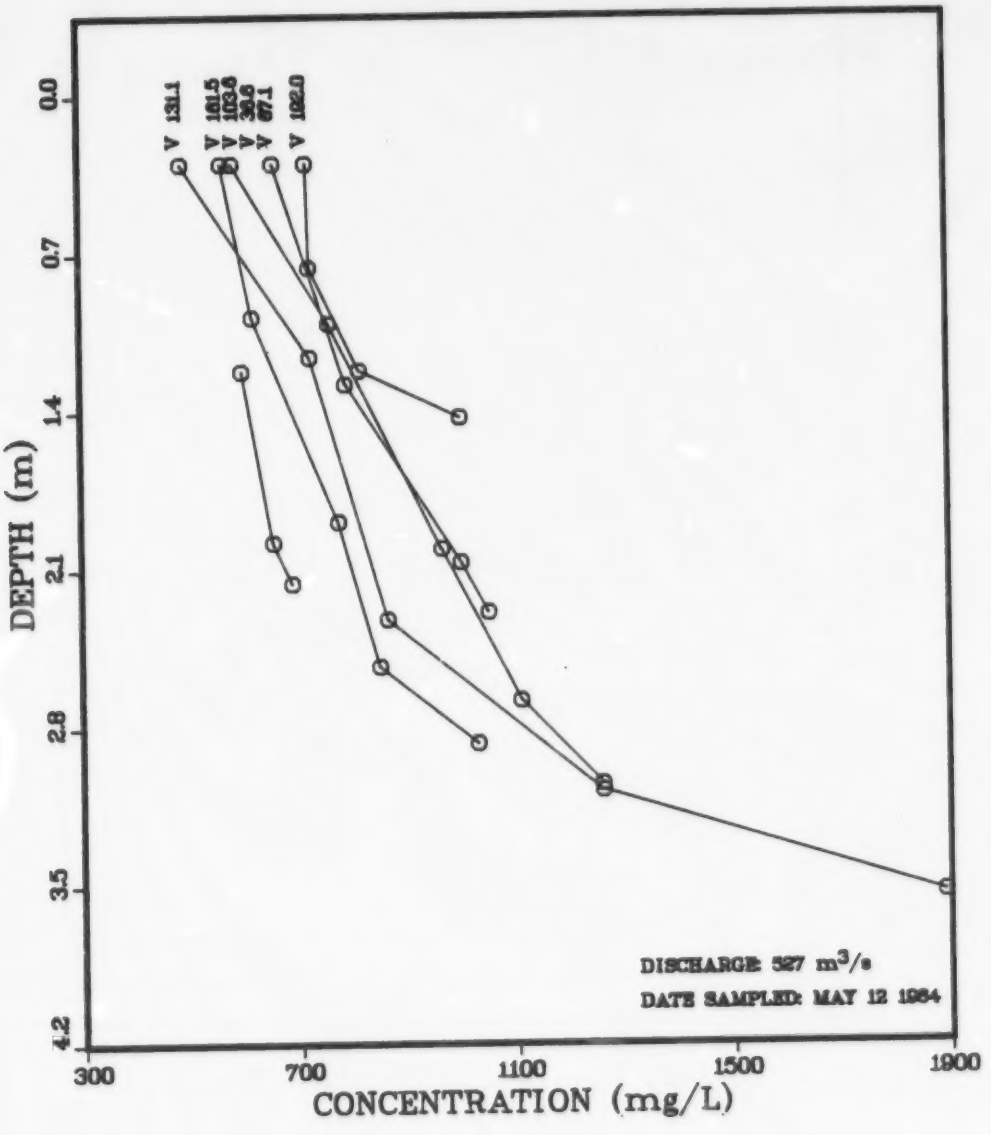
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



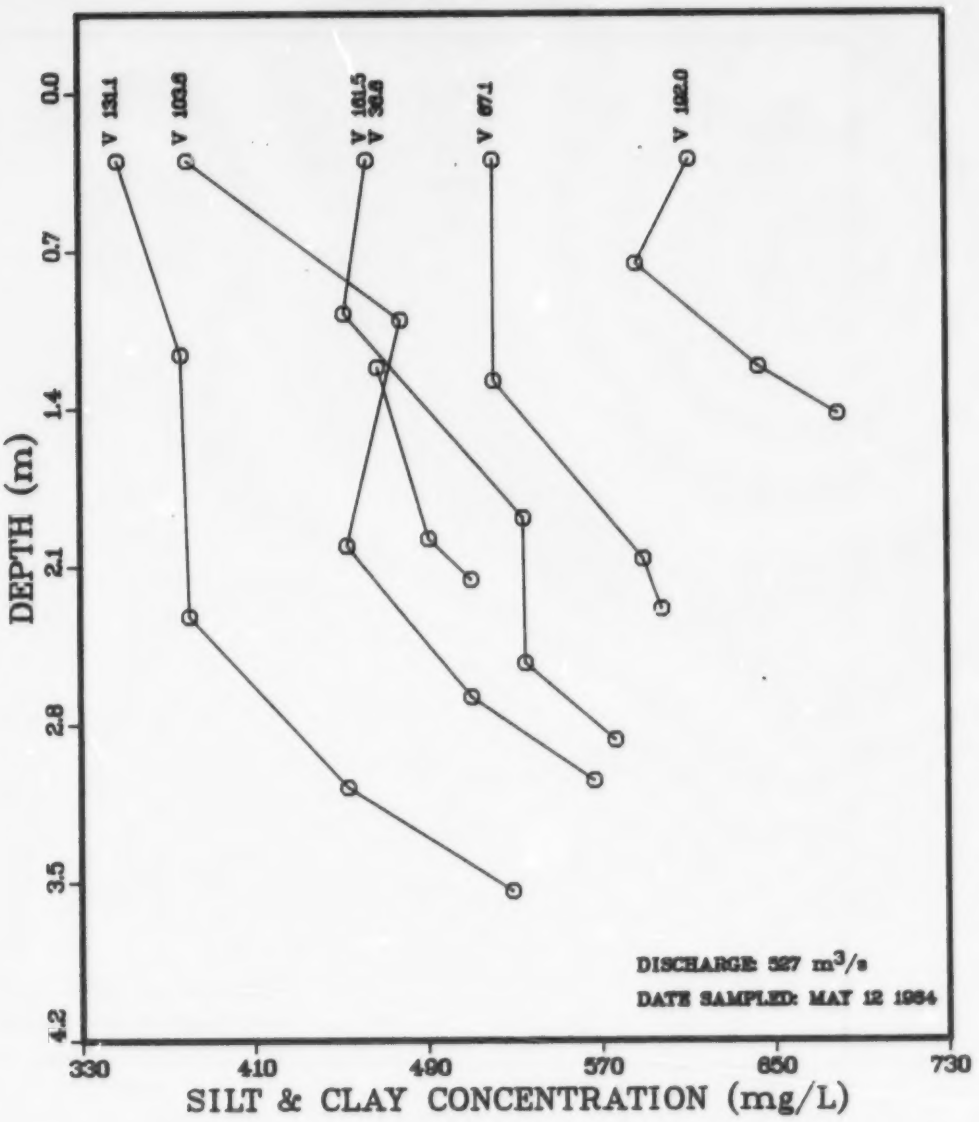
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



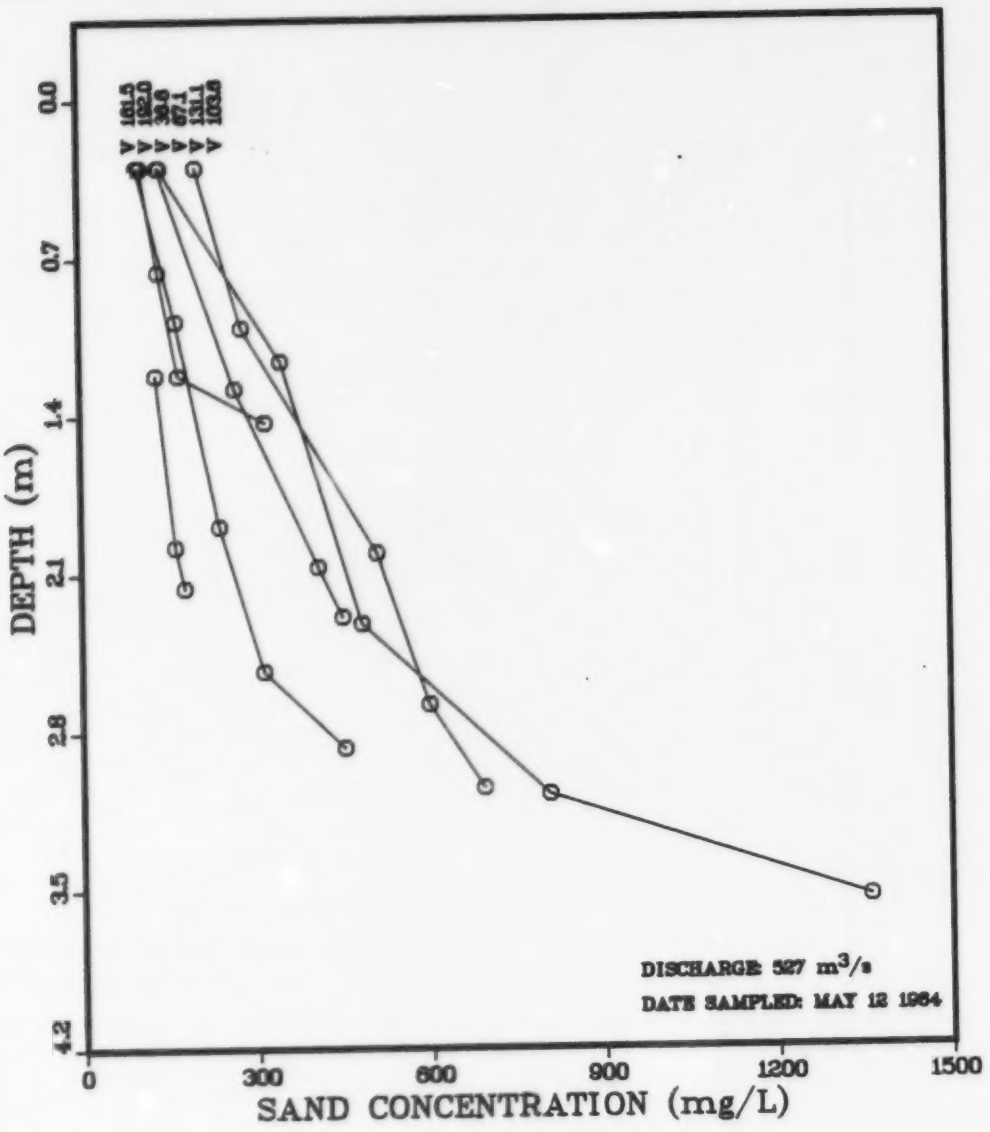
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



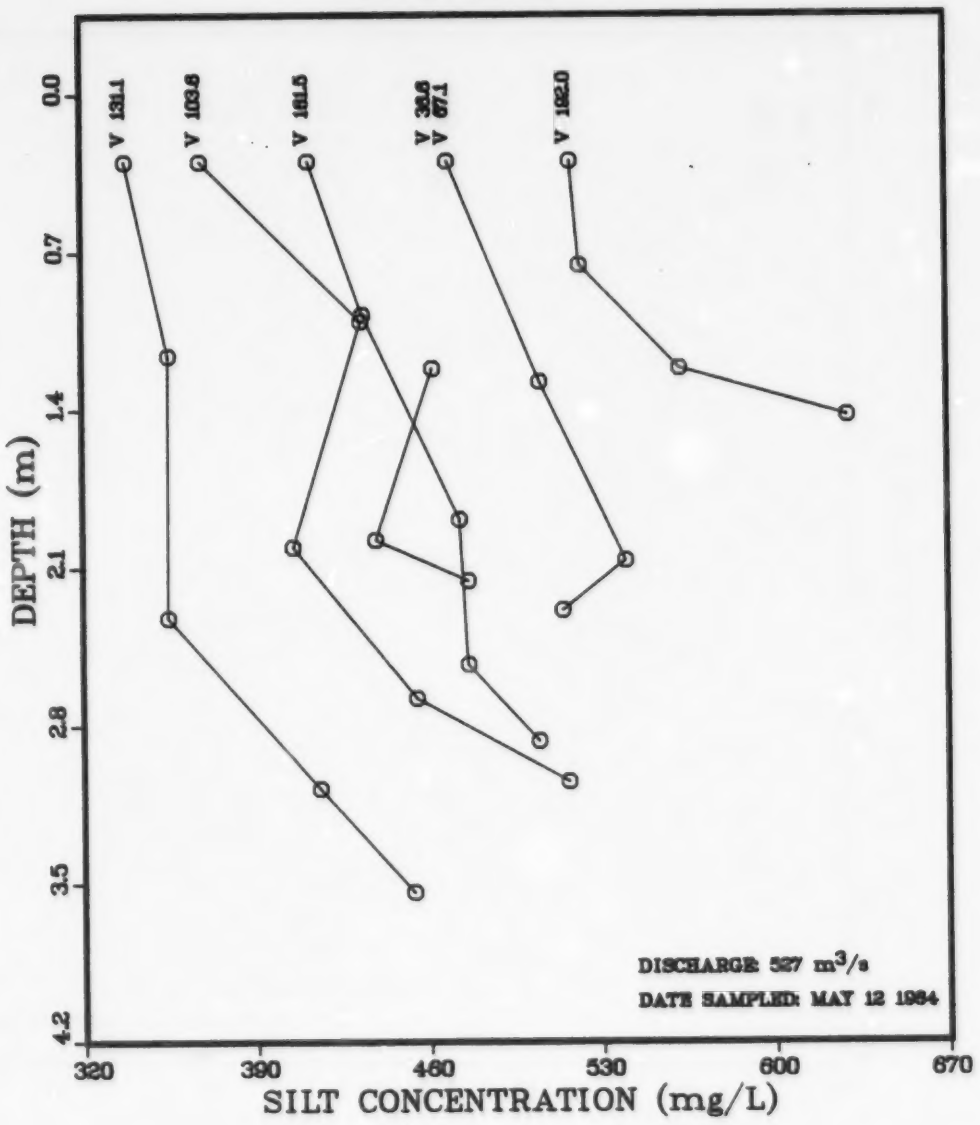
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



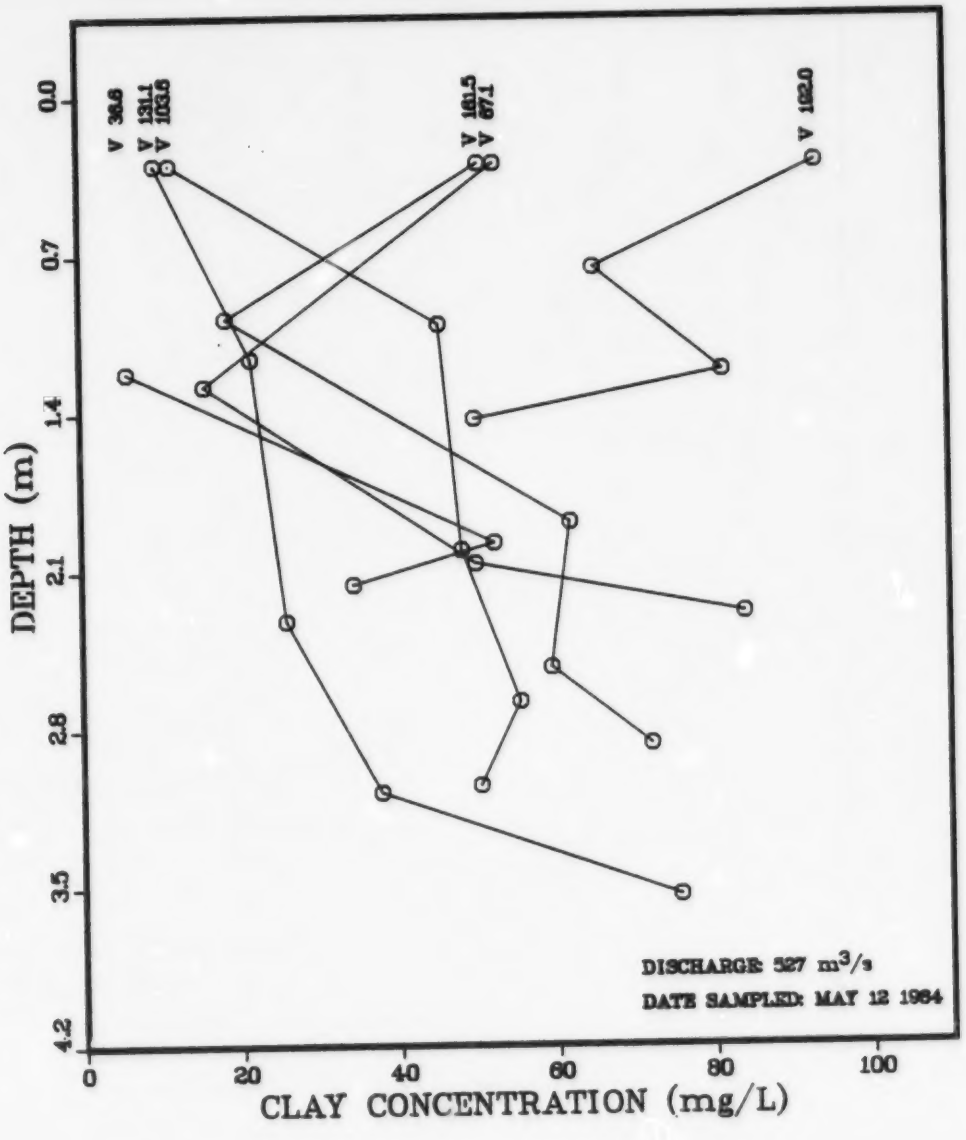
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



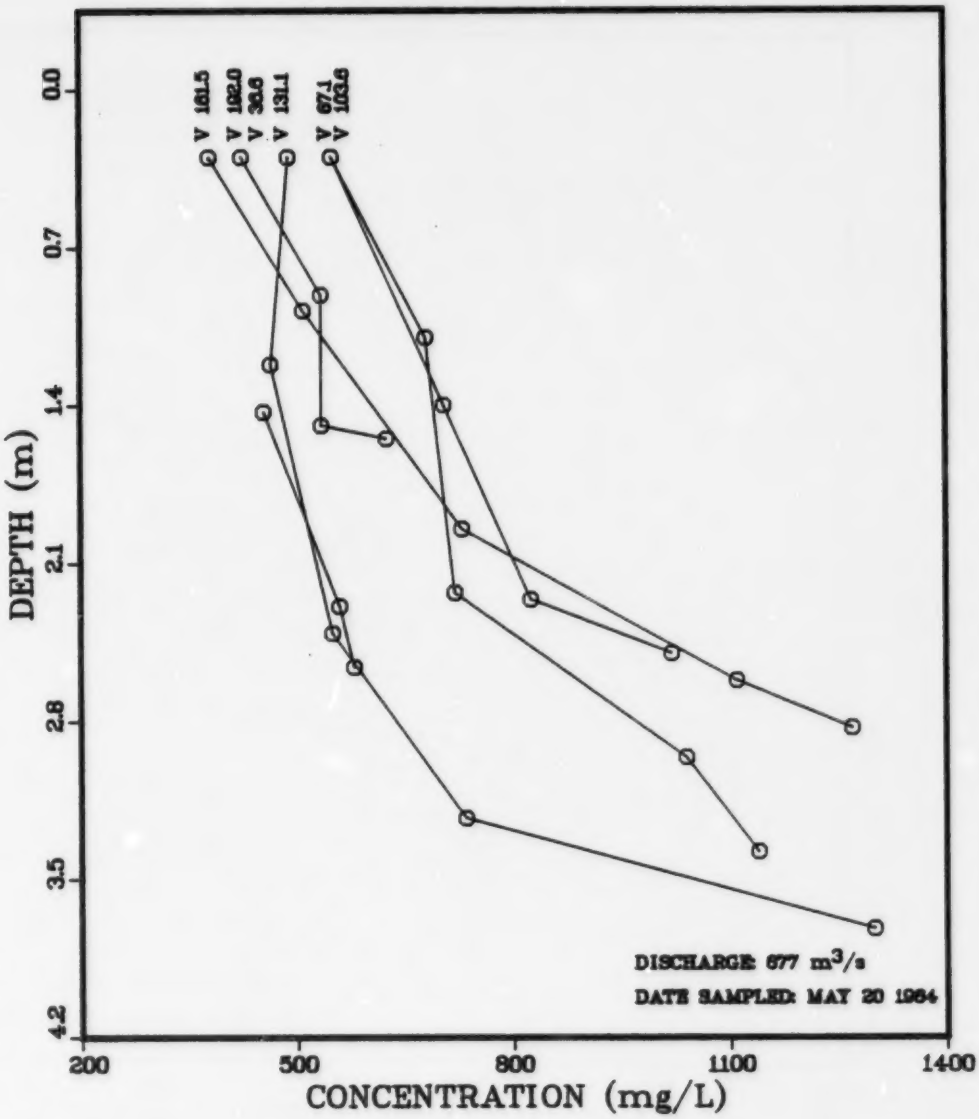
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



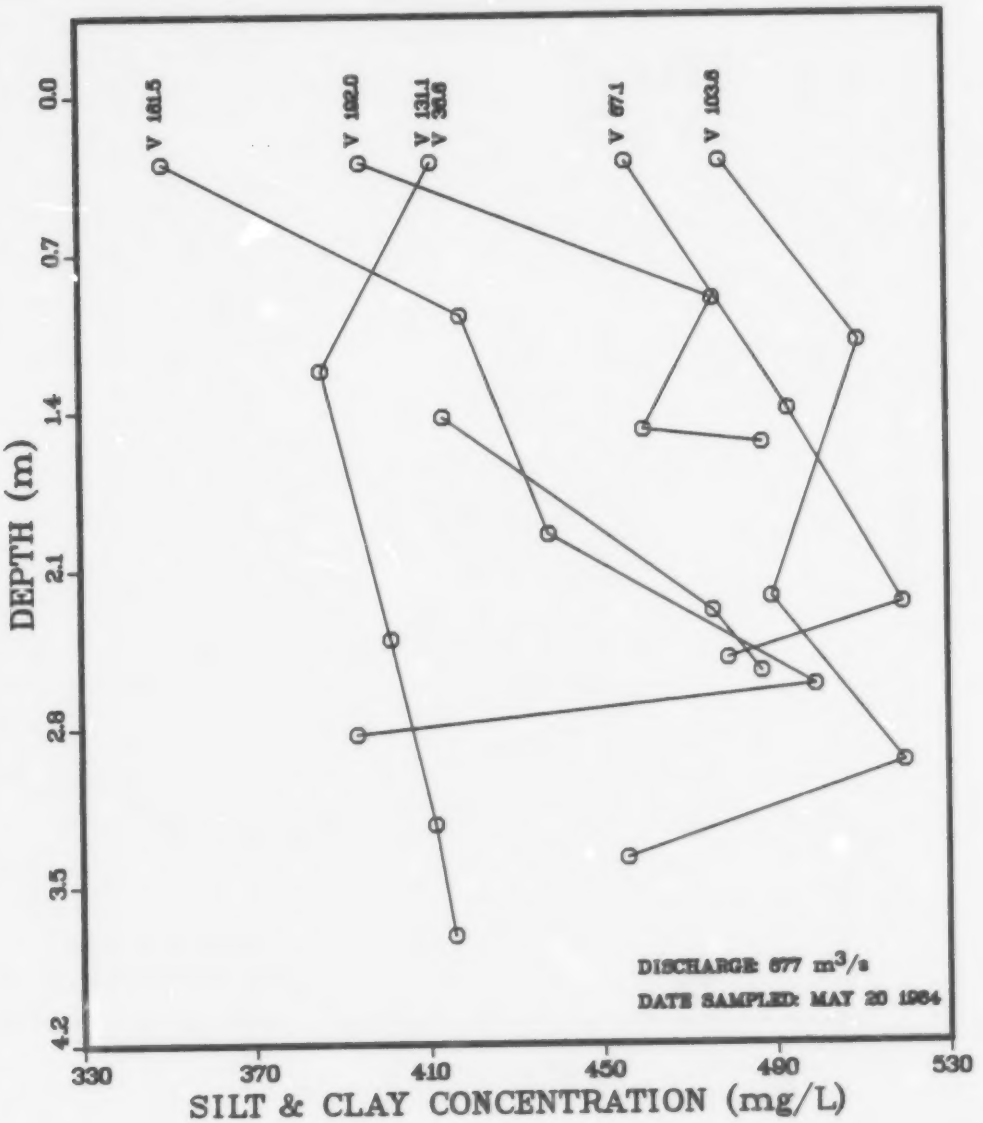
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



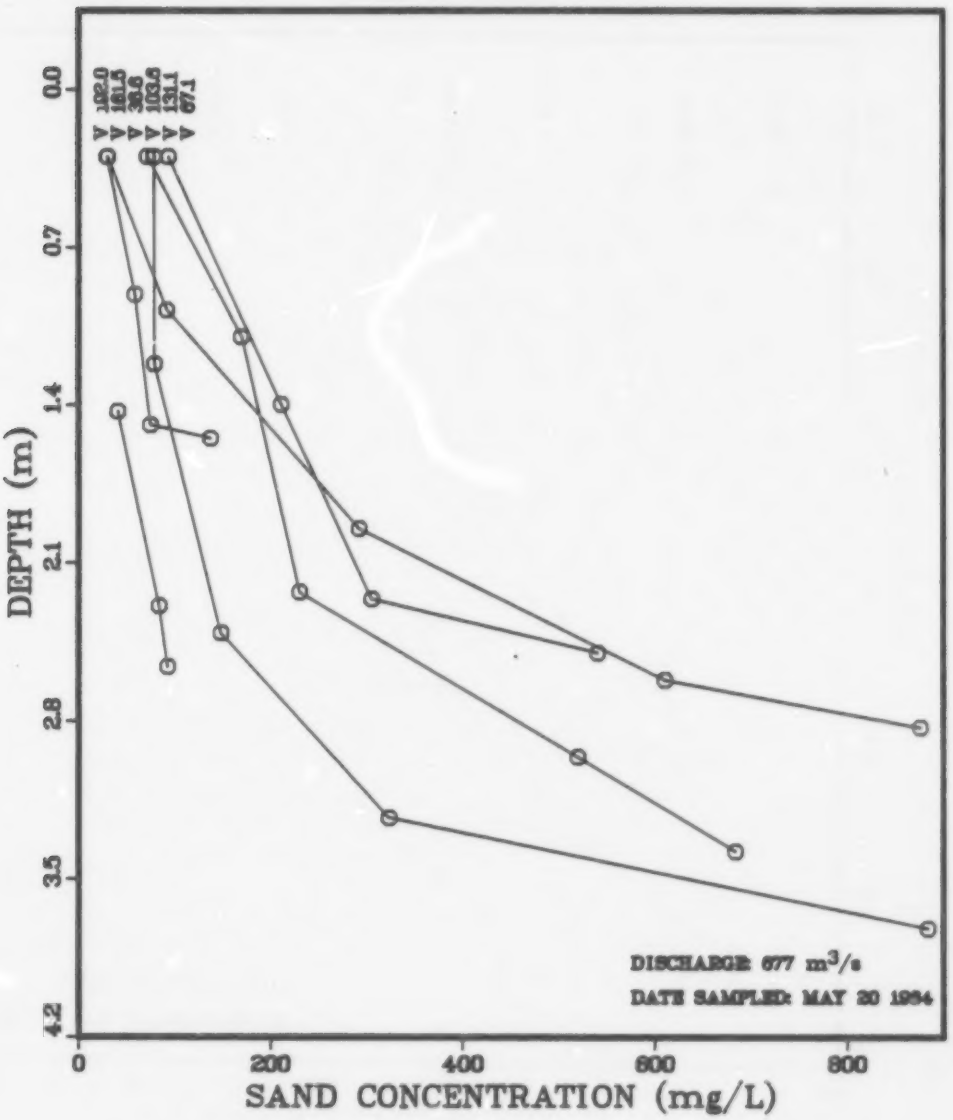
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



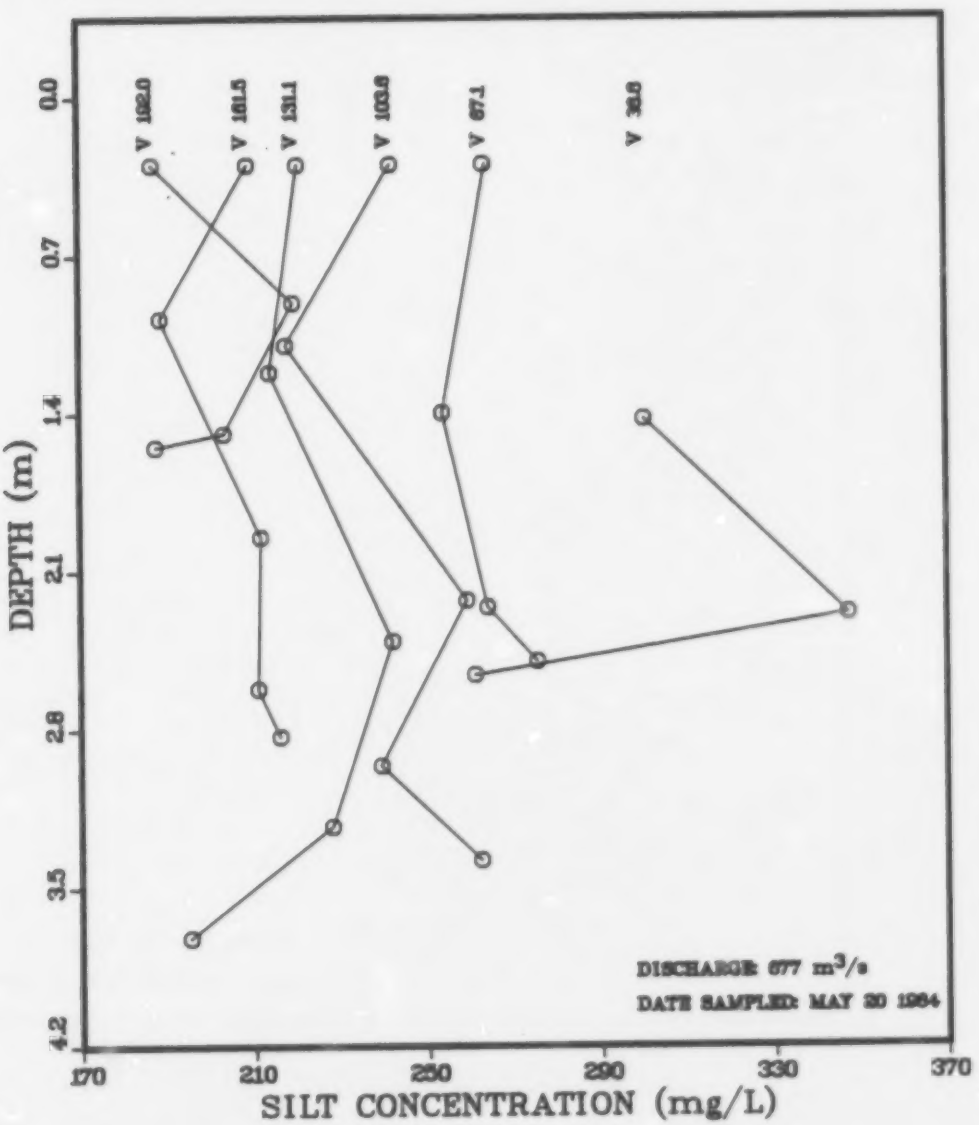
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



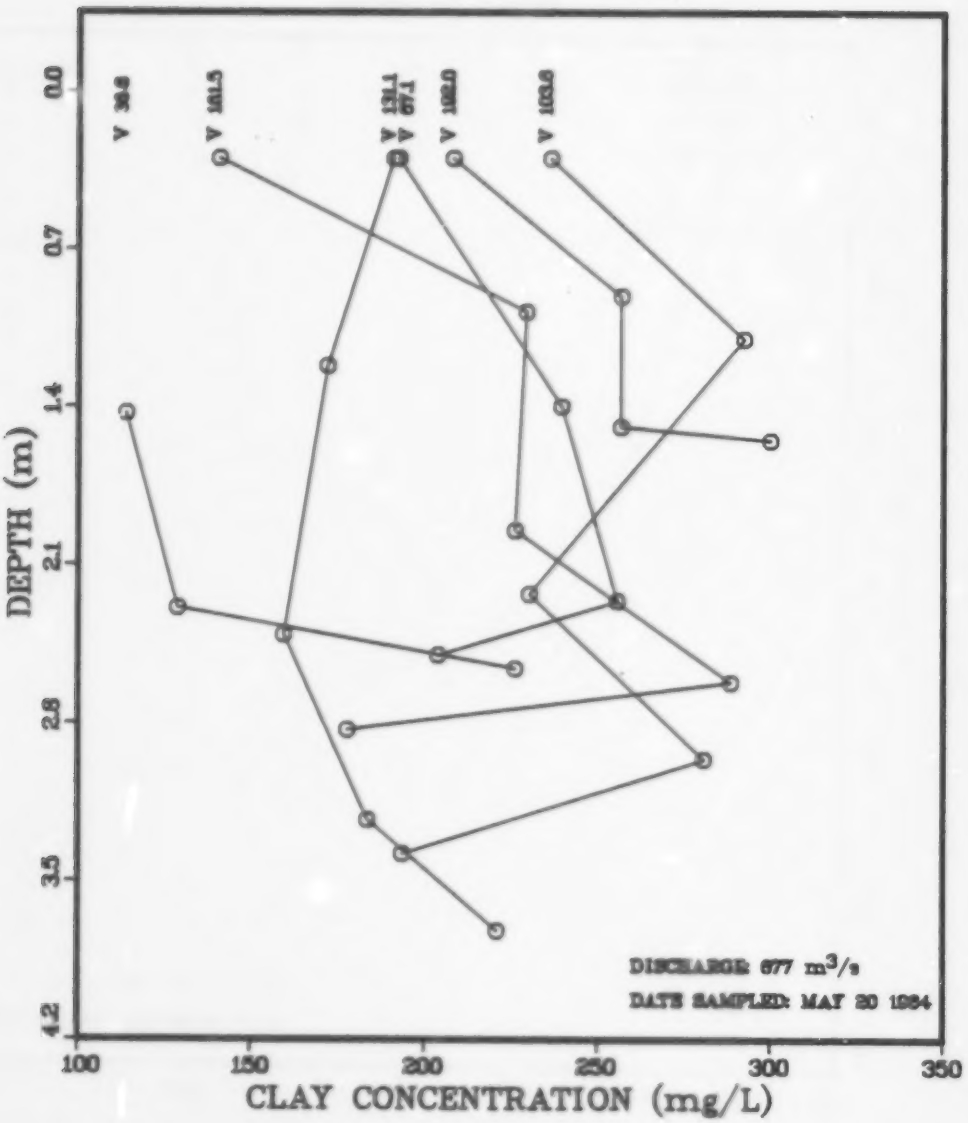
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



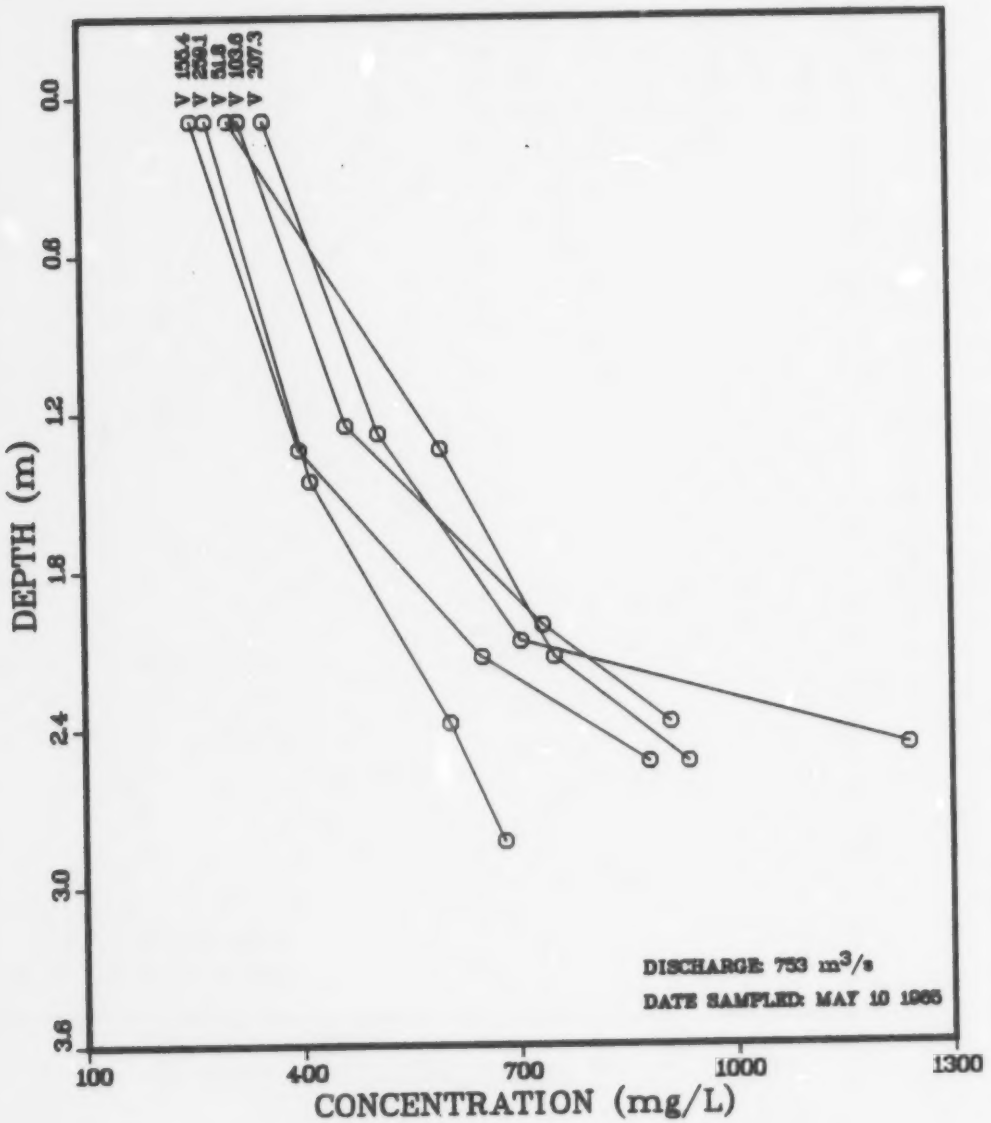
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



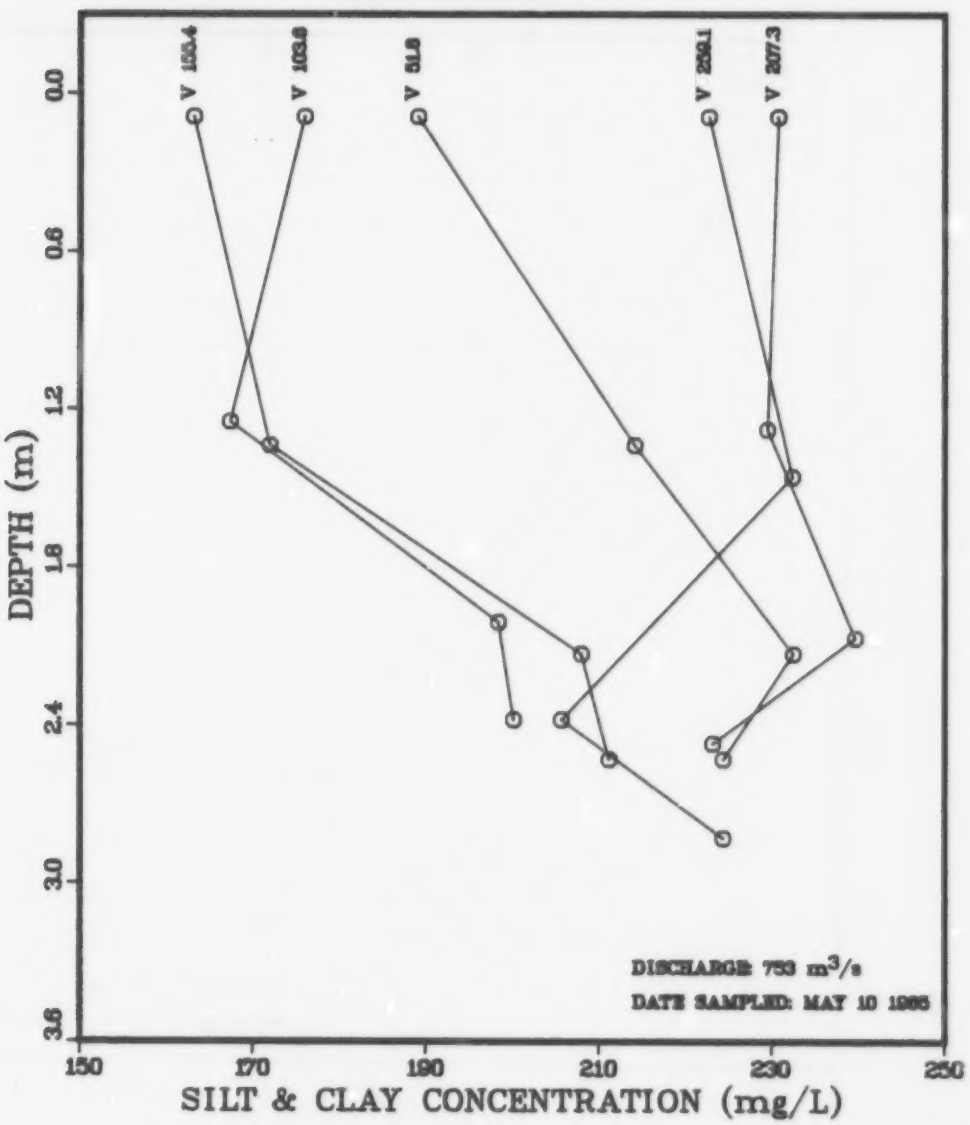
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



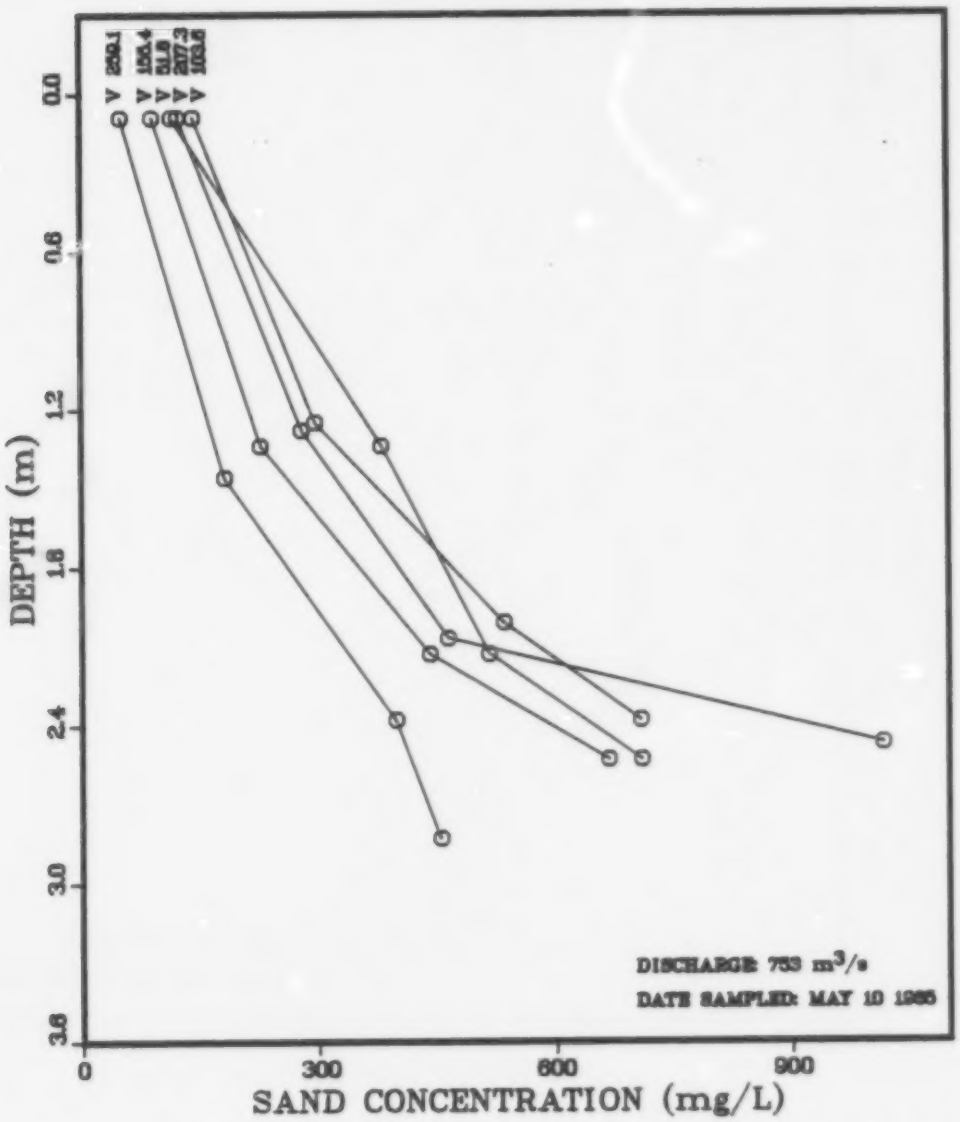
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



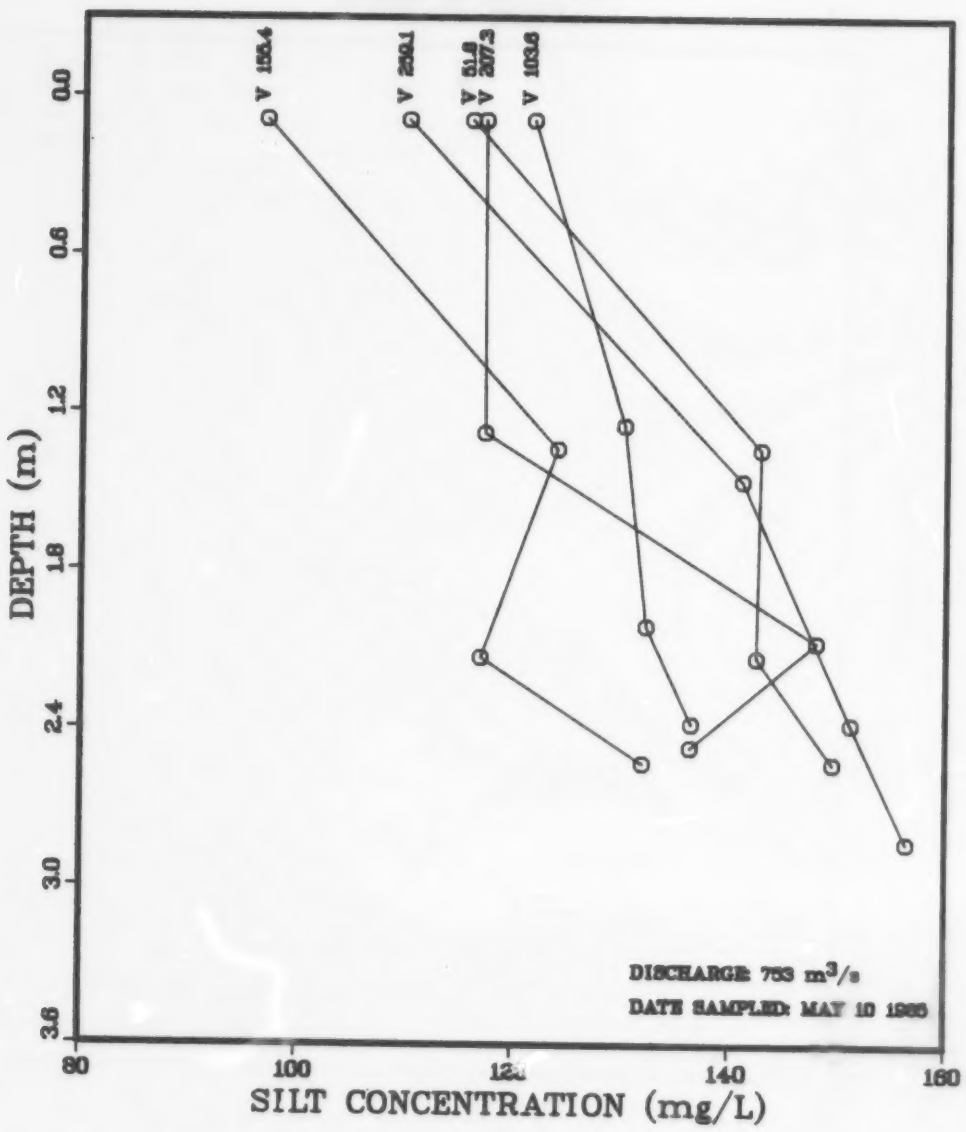
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



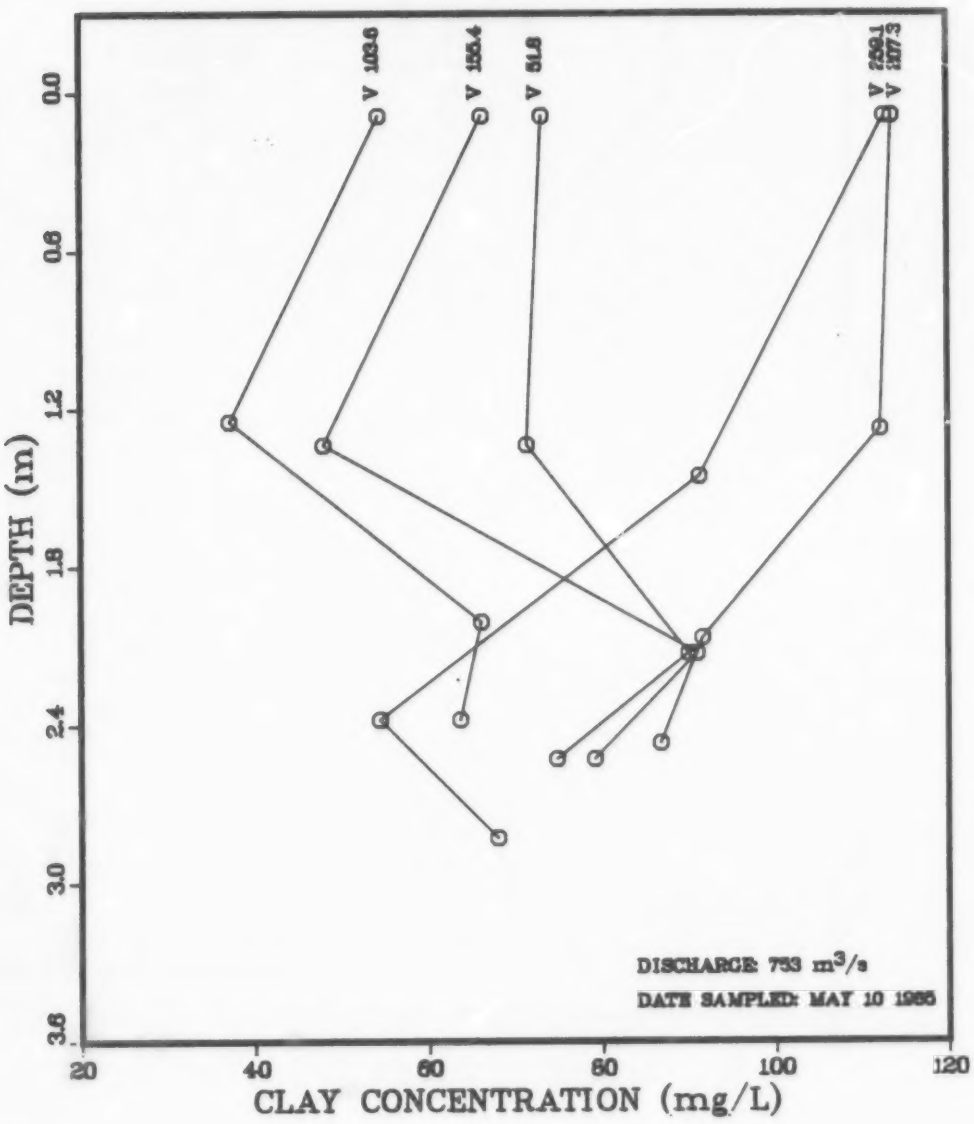
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



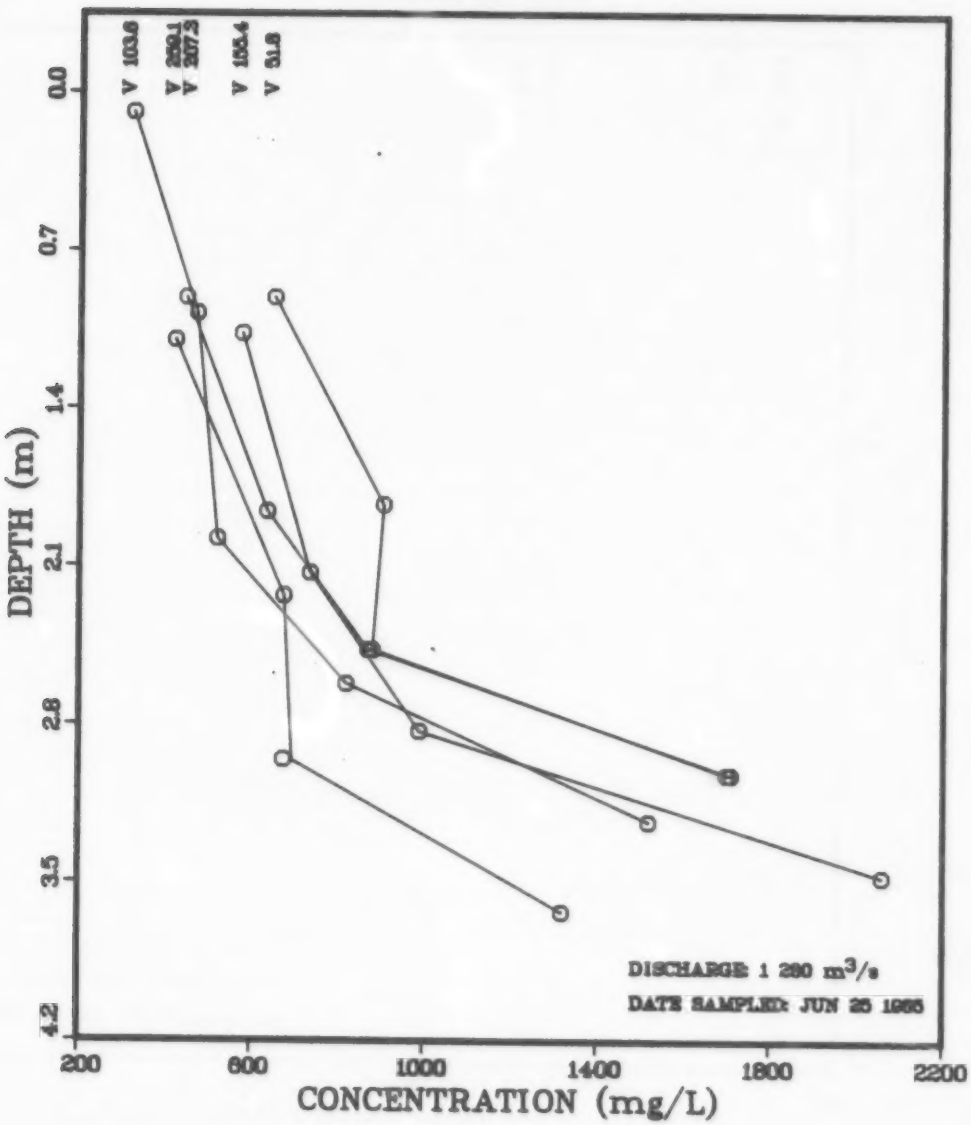
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



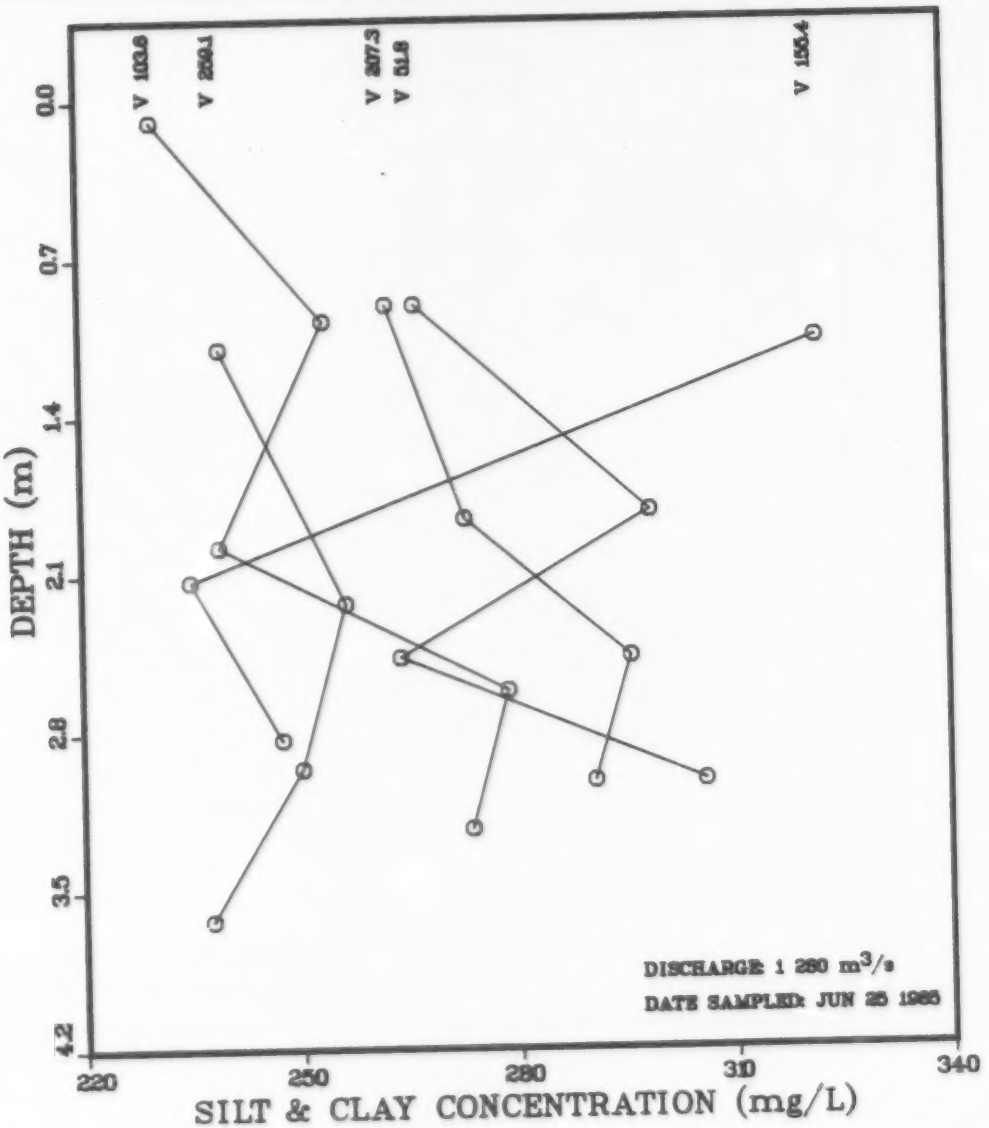
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



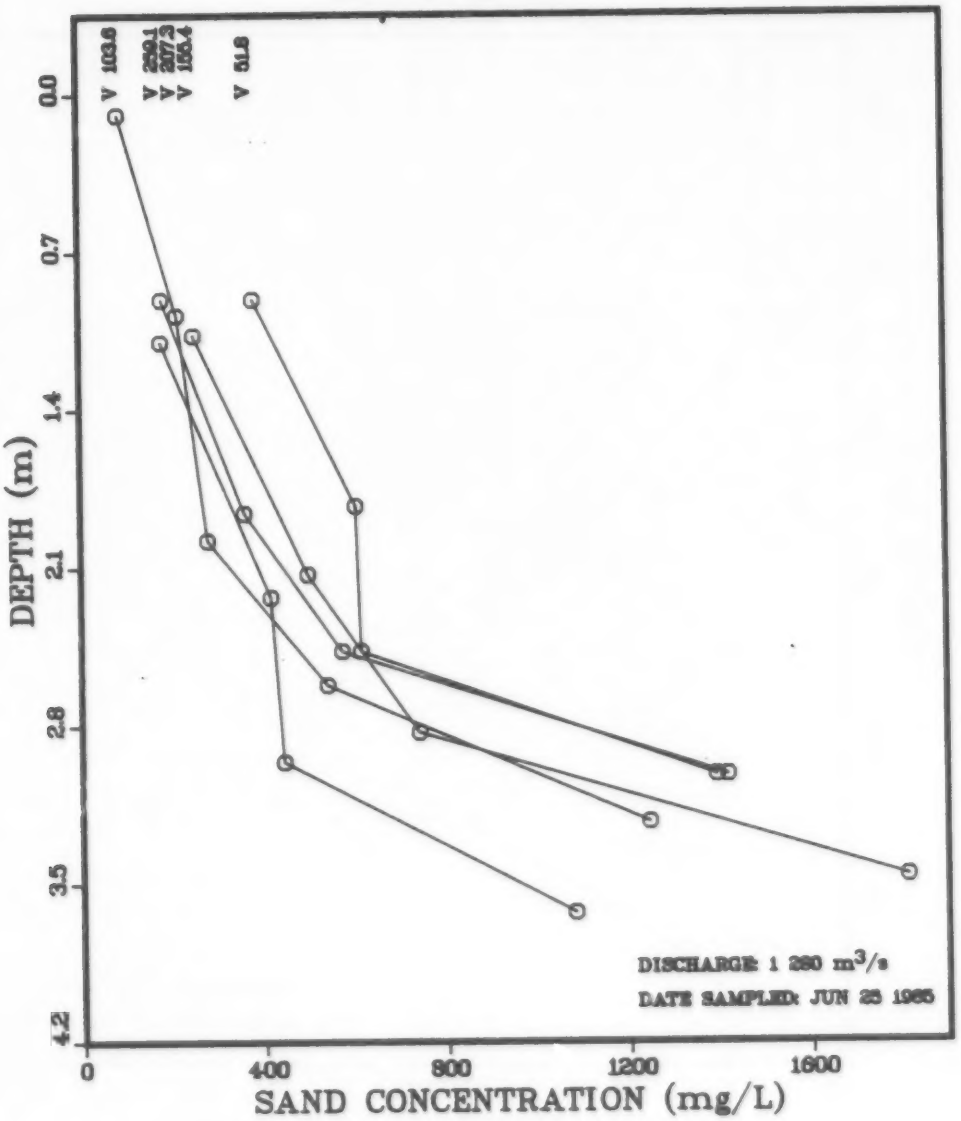
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



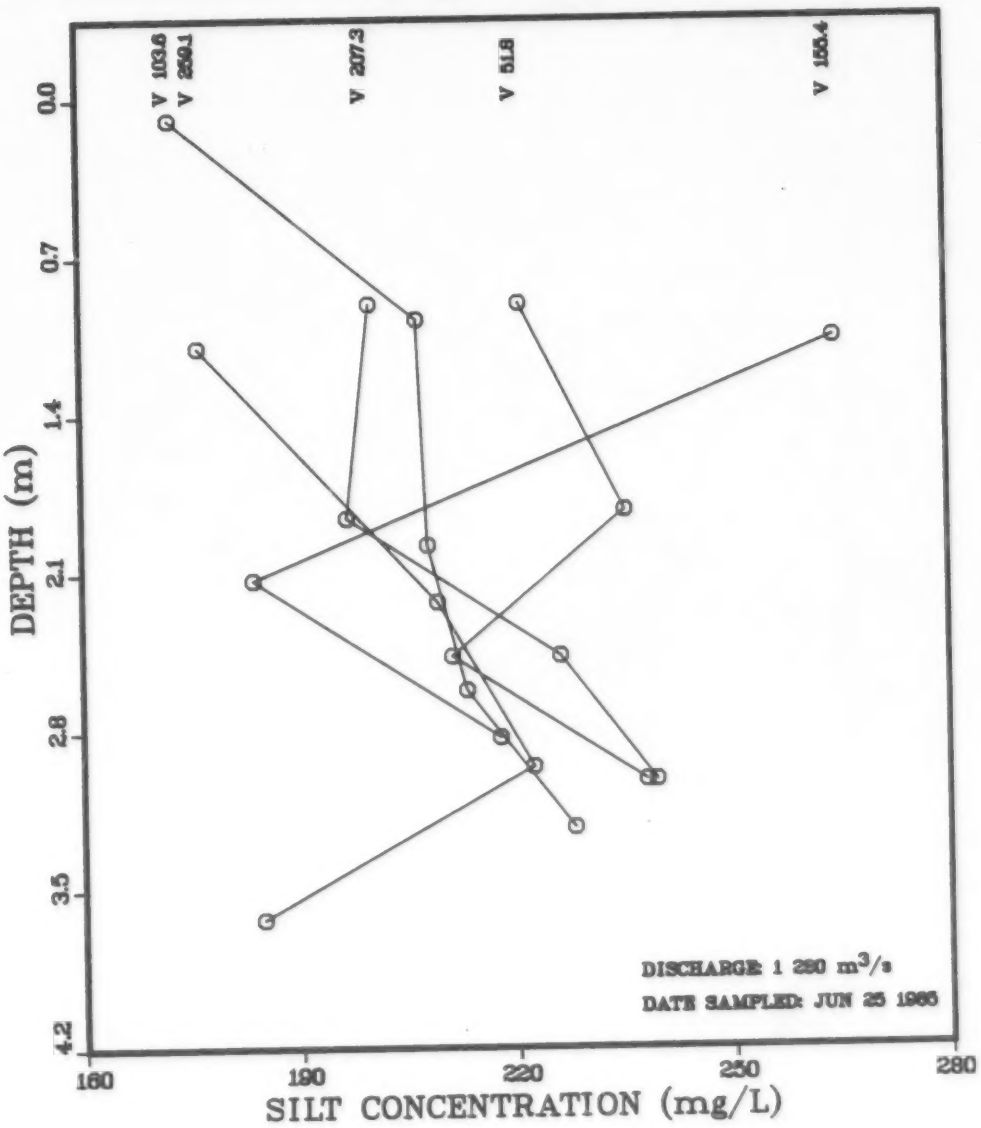
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



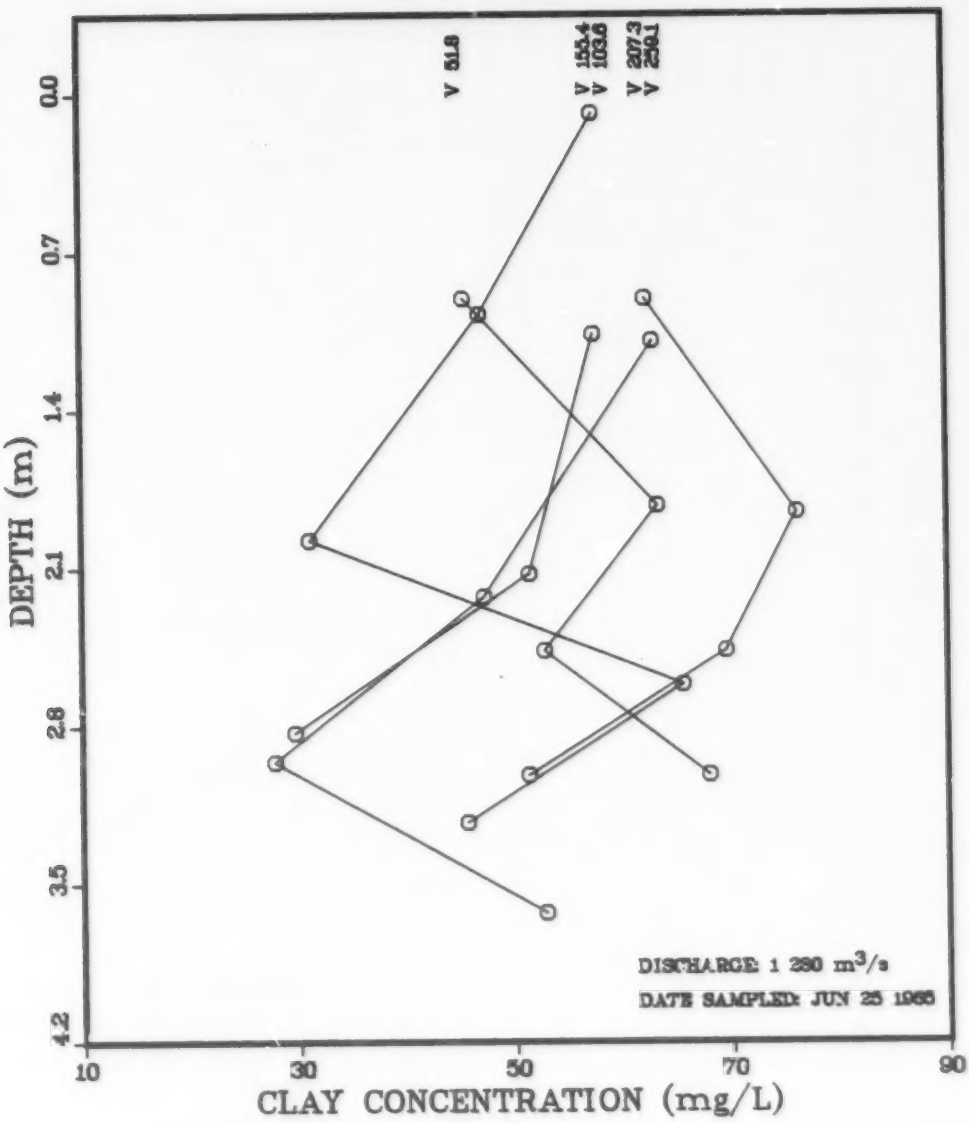
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



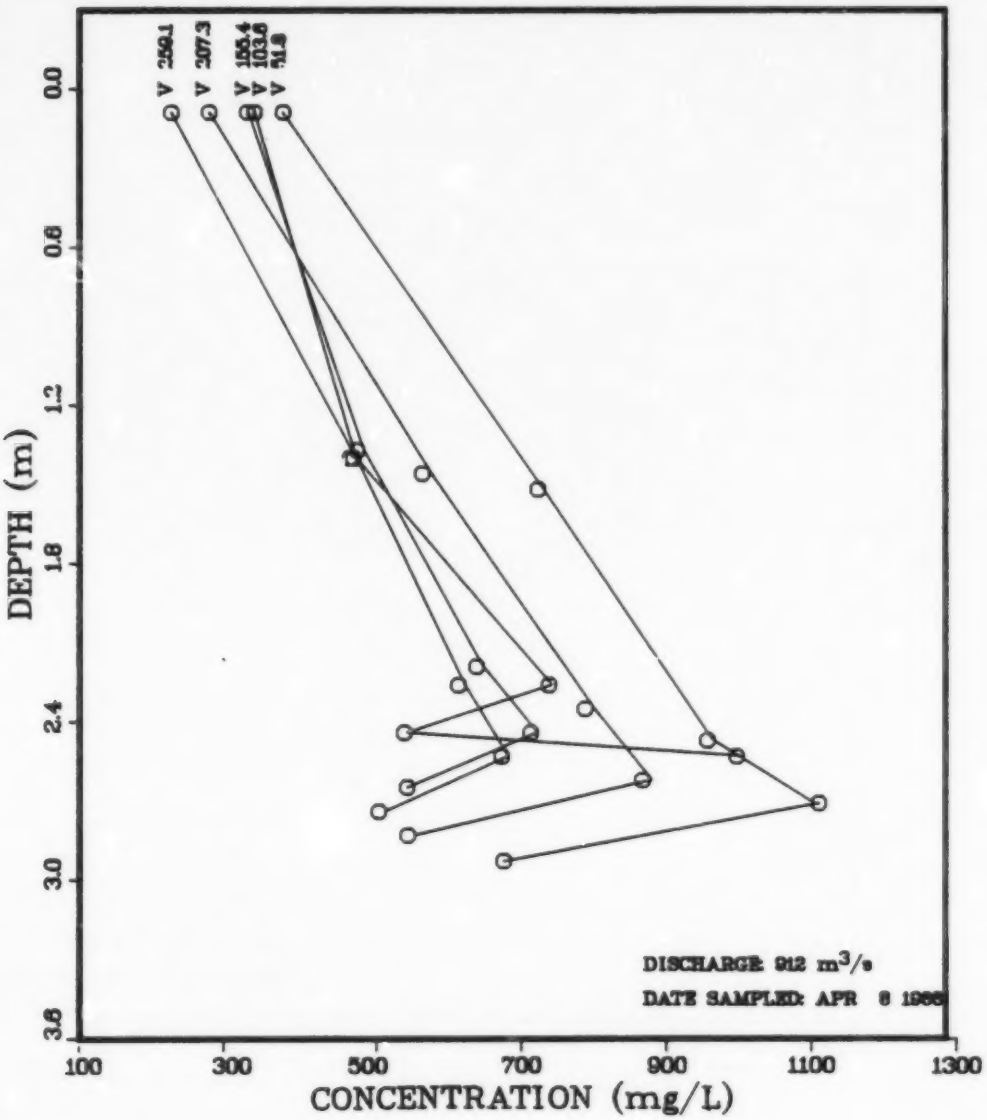
SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



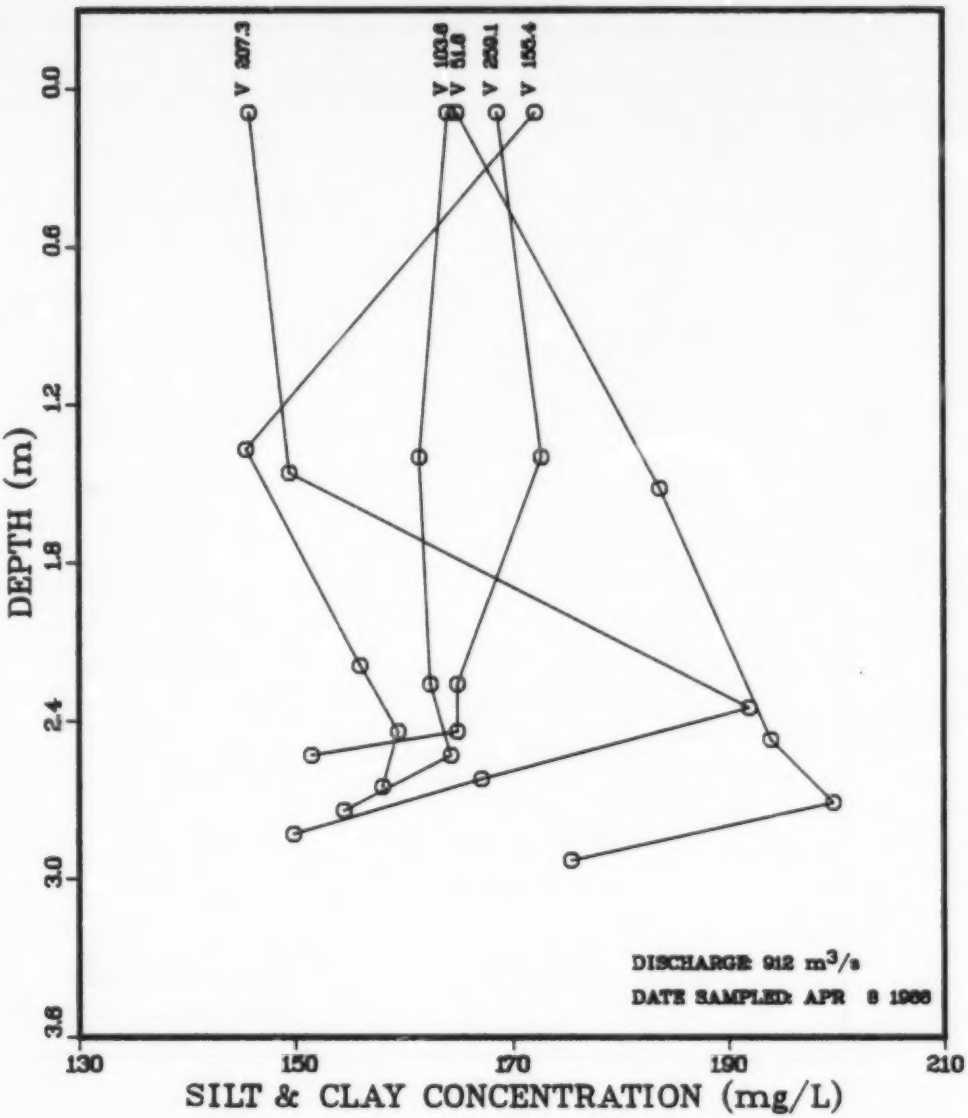
SOUTH SASKATCHEWAN RIVER AT SASKATOON

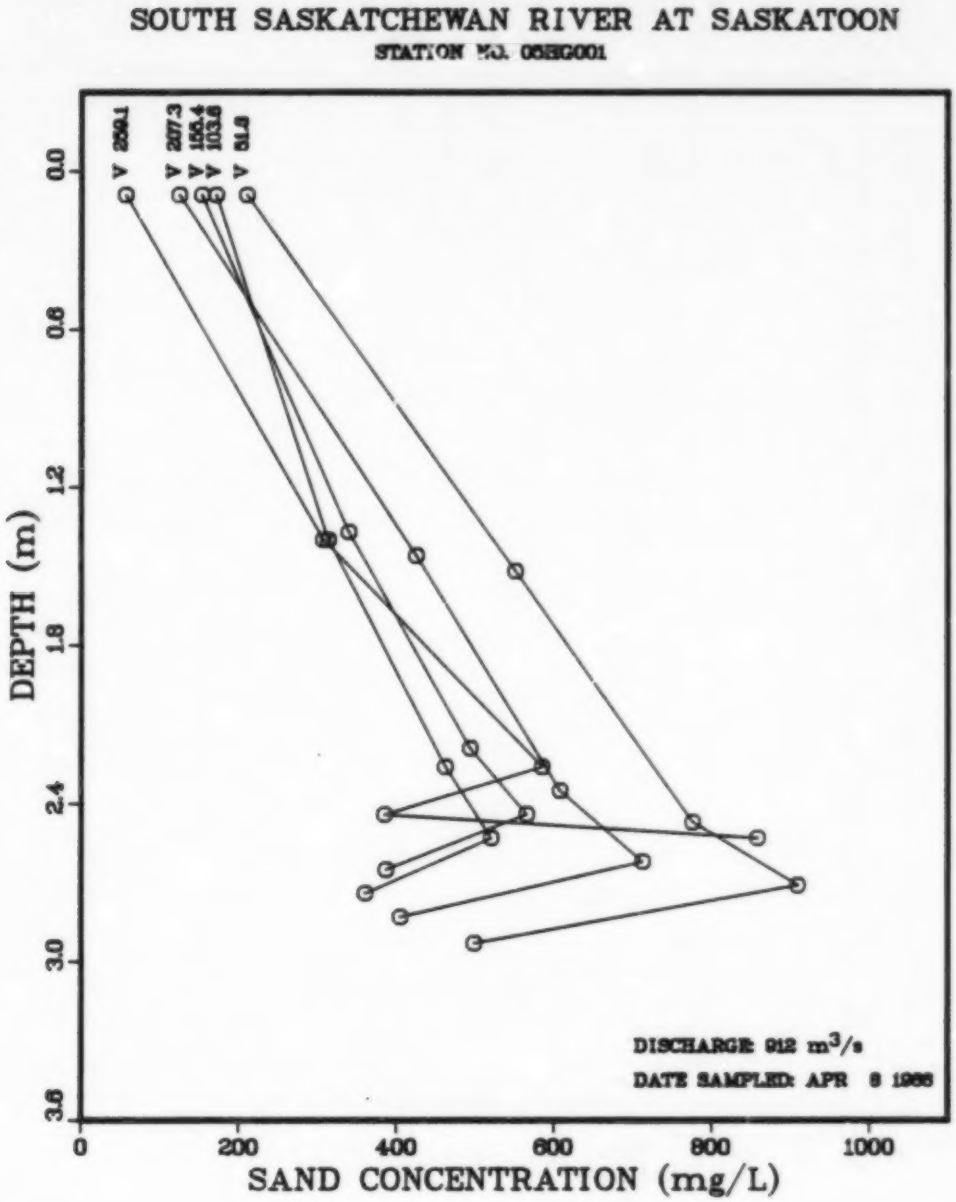
STATION NO. 05HG001



SOUTH SASKATCHEWAN RIVER AT SASKATOON

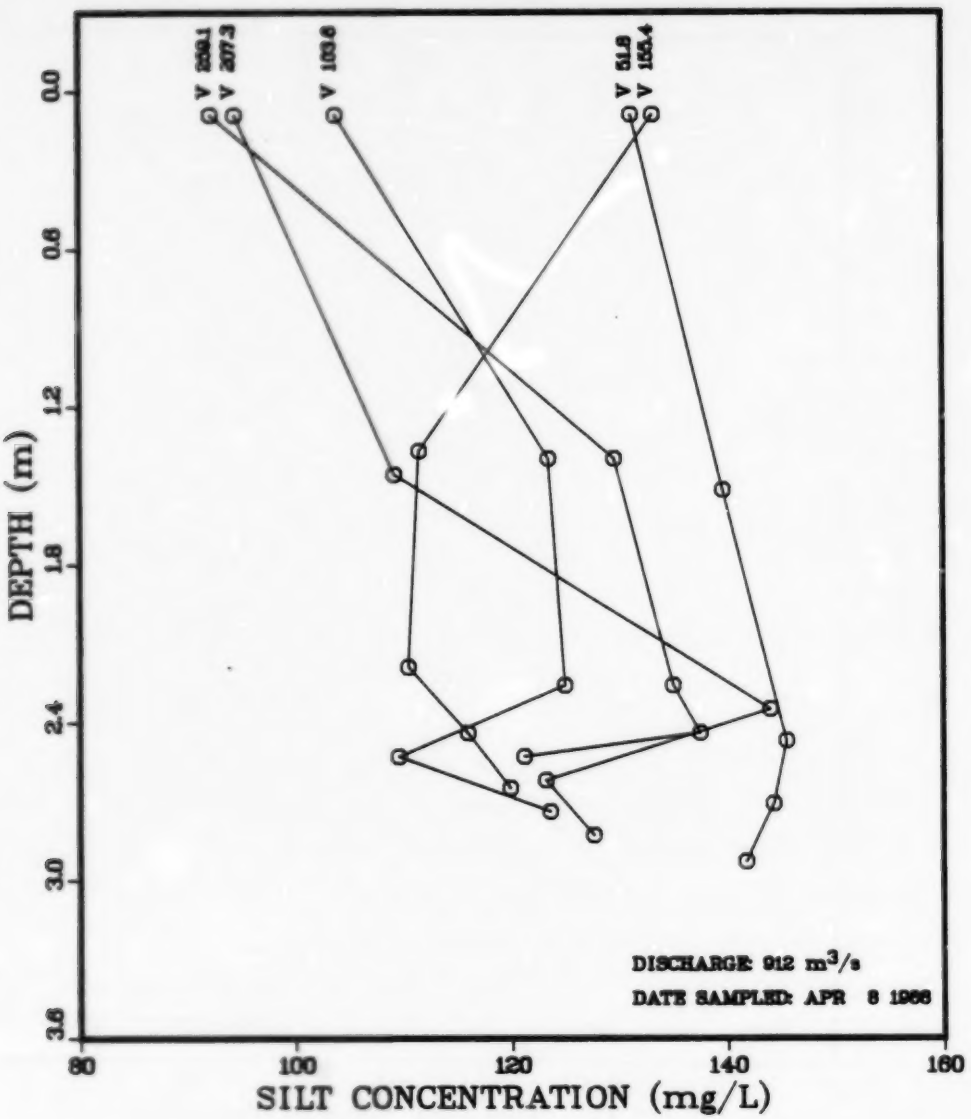
STATION NO. 05HG001

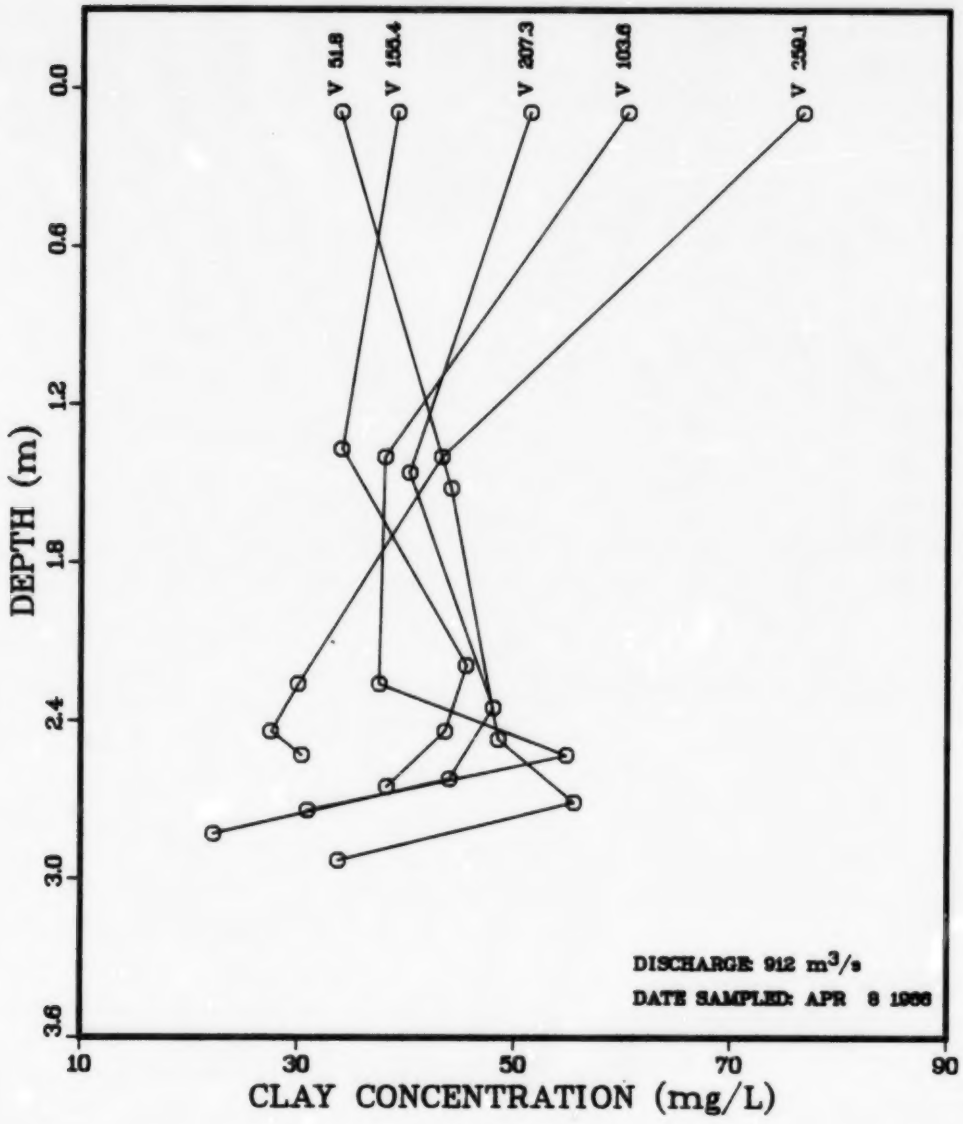



SOUTH SASKATCHEWAN RIVER AT SASKATOON
STATION NO. 05HG001
DEPTH (m)
0.0
0.6
1.2
1.8
2.4
3.0
3.6
0
200
400
600
800
1000
SAND CONCENTRATION (mg/L)
DISCHARGE 912 m3/s
DATE SAMPLED: APR 8 1988

SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001



SOUTH SASKATCHEWAN RIVER AT SASKATOON

STATION NO. 05HG001